Attacking DNAPLs with rapid injection
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Hitting close to home

I grew up in a small town in central Kansas, about 20 miles from a military base. The military base didn’t affect me in many ways, other than it was where my dad was stationed when he met my mom. So maybe it affected me more than I think!

I was surprised to read recently about that base on the front page of my hometown’s paper. It seems that a popular racetrack has been closed for the season because the water source has been contaminated by chemicals dumped from the military site. The owners of the track are suing the government for $1.2 million.

The owners of the track tried importing water. But it has been a very hot summer in central Kansas, and the supply of clean imported water could not keep up with the demand.

Military site cleanup will keep the government busy for many, many years. In the meantime, small business owners pay the price of waiting it out. Fortunately, cleanups are happening and new technologies are finding success in cleaning up the difficult contaminants generated by the work done for our nation’s defense.

Some of these sites are profiled in this issue. And, I have no doubt that the stock car will once again break the quiet of a sleepy, summer Kansas evening!

Jody Becker
Managing Editor

Correction

In the article “Delaware tackles UST sites with mobile remediation system” in June issue of Soil & Groundwater Cleanup, the pressure measurements should be read as kilopascals (KPa) instead of kilopascals of water column. The editor regrets the misunderstanding.

The number for the Government Printing Office as printed in the article “Study points to new trends in use of alternative technologies at LUST sites” in the July issue was incorrect. To order the publications listed on page 16, call 202-512-1800.
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A technician checks an active injector at an industrial facility.

Photo courtesy of Geo-Cleanse International Inc., Kenilworth, N.J.

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Above, the Geo-Cleanse Treatment Program and injection is underway at an industrial facility in Connecticut. Right, a technician checks an active injector at an industrial facility.

**Rapid Delivery System Completes Oxidation Picture**

Remediation of chlorinated solvents at two government sites tests capabilities

By J. Daniel Bryant, Ph.D. and James T. Wilson

Dense non-aqueous phase liquids (DNAPLs) in soil and groundwater pose daunting challenges for environmental remediation. Problems begin with delineation of contaminated soil and groundwater and continue with selecting a remediation alternative that meets both the cleanup objectives imposed by regulators and the cost restraints imposed by clients. The challenges of DNAPL remediation have led to research, development and improvement of numerous ex-situ and in-situ alternatives, including pump-and-treat, soil vapor or dual phase extraction, air sparging and reactive wall technologies.

One emerging technology is in-situ chemical oxidation using Fenton's reagent. Chemical
oxidation with Fenton’s reagent is widely used in ex-situ and wastewater treatment of recalcitrant organic contaminants, including chlorinated solvents and polycyclic aromatic hydrocarbon. Recent advances in development of chemical oxidation include technologies to deliver and distribute reagents in soil and groundwater for in-situ remediation of chlorinated solvents, at contaminant concentrations ranging from the ppb level to free-phase DNAPL.

A Fenton’s reagent primer

H.J.H Fenton first reported in 1894 that malic acid was rapidly oxidized by hydrogen peroxide in the presence of ferrous iron. The oxidation mechanism resulting from solutions of hydrogen peroxide and ferrous iron, referred to as Fenton’s reagent, was later identified as a free hydroxyl radical (OH) formed by the reaction:

\[ \text{H}_2\text{O}_2 + \text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{OH}^- + \text{OH}^+ \]

The OH• generated by Fenton’s reagent is a powerful, non-selective oxidant, second only to fluorine in oxidizing power. Oxidation of an organic compound by Fenton’s reagent is rapid and exothermic. Rate constants for reactions for OH• with common environmental pollutants are typically in the range of \(10^2\) to \(10^{10}\) M\(^{-1}\)s\(^{-1}\), and 100 percent mineralization is generally complete in minutes. Fenton’s reagent has been widely used for ex-situ chemical oxidation of common wastewater and environmental pollutants, but in-situ application technologies have only recently become available. See figure 1, page 7.

A possible concern in choosing in-situ treatment alternatives is continues on page 8 →

Figure 1: Representative list of common environmental pollutants oxidized by Fenton’s reagent, based on laboratory and field studies

Aromatic and polycyclic hydrocarbons
- BTEX (benzene, toluene, ethylbenzene, and xylene)
- SVOCs (semi-volatile organic compounds, such as naphthalene, anthracene, phenanthrene, pyrene)
- Other petroleum hydrocarbons
- Nitrocumaric munitions, such as trinitrotoluene (TNT) and dinitrotoluene (DNT)

Phenolic compounds
- PCBs (polychlorinated biphenyls)
- Herbicides and pesticides (pendimethalin, chlorosulfuron, lindane, seldane, pentachlorophenol, chlorophenoxyis)

Chlorinated solvents
- Alkyls, such as trichloroethene, perchloroethene, dichloroethene
- Alkane, such as trichloroethane, dichloroethane

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formation of hazardous intermediate products. Fenton’s reagent oxidation of complex organic compounds produces a number of intermediate products, most of which are very short-lived and are also oxidized, ultimately yielding carbon dioxide, water, and for some compounds, chloride and nitrate.

Naturally-occurring carboxylic acids are the only significant intermediate oxidation products of Fenton’s reagent treatment of organic compounds. Production of carboxylic acids from oxidation of petroleum hydrocarbons and chlorinated solvents has been demonstrated in the field in one study. See figure 2, page 9.

A second concern is injection of hydrogen peroxide into the subsurface and possible hazards posed to the subsurface environment. Although hydrogen peroxide is a strong oxidizer, it is an environmentally safe groundwater and soil amendment. Hydrogen peroxide injection as an oxygen source for enhancing bioremediation has been widely used. In-situ chemical oxidation technologies typically use more concentrated hydrogen peroxide solutions — up to 50 percent solutions — compared to the <1,000 mg/L solutions injected for typical bioremediation applications.

In the subsurface, hydrogen peroxide is unstable and naturally decomposes rapidly to water and oxygen. Furthermore, decomposition is enhanced by the presence of common transition metals found in soil and groundwater. After injection, hydrogen peroxide concentrations outside the treatment area are usually below the mg/L level and rapidly diminish to nondetectable levels within several days.

Decomposition of excess hydrogen peroxide will result in elevated dissolved oxygen levels throughout the treatment area following injection and thus will aid aerobic microbial consumption of contaminants.

A technology for contaminated sites

A technology for delivering Fenton’s reagent to the subsurface has been developed and patented by Geo-Cleanse International Inc., (GCI) Kenilworth, N.J. This process rapidly injects and distributes hydrogen peroxide and catalyst solution through the formation for in-situ oxidation, via mixing heads and injectors designed to withstand the higher temperatures and pressures generated by Fenton’s reagent. The process has been applied to more than 40 sites in 14 states and in Canada. Two recent applications to remediate plumes of chlorinated solvent DNAPL in soil and groundwater have been intensively studied.

Savannah River Site: A
Figure 2: Carboxylic and dicarboxylic acids derived from Fenton’s oxidation of organic contaminants in groundwater at a site contaminated by chlorinated solvents, primarily 1,1,1-trichloroethane, and petroleum hydrocarbons (polycyclic aromatic hydrocarbons, primarily derived from diesel fuel). The project was a joint venture by Geo-Cleanse International Inc., R.F. Weston Inc. and the U.S. Army Corps of Engineers.

<table>
<thead>
<tr>
<th>Carboxylic acid</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stearic acid</td>
<td>1200 mg/L</td>
</tr>
<tr>
<td>Lauric acid</td>
<td>310 mg/L</td>
</tr>
<tr>
<td>Tetradecanoic acid</td>
<td>Trace</td>
</tr>
<tr>
<td>Hexadecanoic acid</td>
<td>Trace</td>
</tr>
<tr>
<td>Octadecanoic acid</td>
<td>Trace</td>
</tr>
</tbody>
</table>

performance demonstration of in-situ chemical oxidation of DNAPL was conducted by a joint venture of GCI, the Westinghouse Savannah River Corp., and the U.S. Dept. of Energy at the Savannah River Site in Aiken, S.C. An estimated 1,600 metric tons of solvents, primarily tetrachloroethene and trichloroethene, were discharged between 1958 and 1985.

The performance demonstration was conducted directly adjacent to the source area, encompassing a volume of about 1,800 m³ at a depth of 43 m below grade, in an aquifer composed of native interbedded and clay-rich sand. Free-phase DNAPL was observed and average groundwater concentrations of tetrachloroethene and trichloroethene were 119.5 and 21.3 mg/L, respectively, with an estimated 269 kg of DNAPL within the treatment area.

A six-day performance demonstration was completed in April 1997, during which about 16,000 L of 50 percent hydrogen peroxide plus catalyst solution were delivered via four high-pressure injectors spanning the contaminated interval of the aquifer. Post-injection sampling indicated destruction of about 253 kg of DNAPL, equivalent to a 94 percent reduction.

Dissolved chloride, an oxidation product of tetrachloroethene and trichloroethene, provides an effective measure of chlorinated solvent DNAPL destruction in groundwater. Significant chloride increases were recorded in addition to large reductions in contaminant concentrations in groundwater. See figure 3, this page. Costs for the in-situ chemical oxidation performance demonstration were $183,000 for reagents and the injection program, excluding consultant oversight and pre- and post-injection characterization.

Figure 3: Average groundwater analytical results for the Savannah River Site. The duration of the six day performance demonstration is indicated by the shaded interval. Tetrachloroethene and trichloroethene destruction averaged 94 percent after the performance demonstration. Chloride ion, which is an oxidation product of chlorinated solvents, increased dramatically. Post-injection rebound occurred due to dissolution of DNAPL from adjacent areas not treated during the performance demonstration.

Anniston Army Depot: The Anniston Army Depot in Anniston, Ala., closed a former unlined industrial waste lagoon in 1978. Hazardous wastes disposed in the lagoon included petroleum hydrocarbons and chlorinated solvents. After closure, much of the lagoon sludge was excavated and the lagoon was backfilled with native clay.

Significant contamination remained, estimated at 32 metric tons of total volatile organic compounds, primarily trichloroethene in a volume of about 10,500 m³ of both unsaturated and saturated soils. The maximum trichloroethene

Continues on page 10 →
concentration was 20,100 mg/kg. Cleanup technologies considered for the site included air, steam and biosparging via horizontal wells, in-situ and ex-situ thermal and biological treatment, and off-site incineration and disposal. Most of these were not technically viable in clay soils or were prohibitively expensive. In a joint venture by GCI, QST Environmental Inc. and the U.S. Army Corps of Engineers, a performance demonstration of in-situ chemical oxidation occurred in December 1996.

The demonstration lasted 18 days. About 30,000 L of 50 percent hydrogen peroxide plus catalyst solution were injected via 20 injectors ranging in depth from 2.3 to 18.3 m below grade in a 232 m² portion of the most contaminated area. Post-injection sampling indicated an average 87 percent reduction (with a range of 47 percent to 100 percent) in volatile organic compounds in the treated area after the demonstration. Based on these results, a full-scale remediation program was initiated and is in progress. About 250 injectors were installed to encompass the plume. The program is scheduled to proceed over five months and deliver about 361,000 L of 50 percent hydrogen peroxide solution. To date, after injection of about 218,000 L of 50 percent hydrogen peroxide over three and a half months, analyses of 30 soil samples indicate trichloroethene destruction ranging from 65 percent to more than 99 percent. See figure 4, page 11. Costs for the in-situ chemical oxidation treatment are an estimated $1.4 million, excluding consultant oversight and pre-and post-injection characterization.

Cost efficiency

Unit costs for in-situ chemical oxidation have a considerable range. Controlling factors include the volume and distribution of contaminated soil or groundwater, the amount and nature of the contaminant, and the hydraulic conductivity of the formation. These factors determine the number of injectors, amount of hydrogen peroxide and other reagents, and time necessary to deliver the reagents to the subsurface, which cumulatively determine the final cost.

Unit costs are less than $50 per kilogram of contaminant oxidized for sites with high levels of DNAPLs and large size. At the opposite end of the spectrum, unit costs can range as high as several hundred dollars per kilogram of contaminant for relatively small sites of tens of square meters with relatively low contamination (µg/L levels dissolved in groundwater). These costs are generally higher than for bioremediation, pump-and-treat, or other passive technologies, but significantly less than for dig-and-haul or incineration technologies. One important advantage of in-situ chemical oxidation, which also affects cost effectiveness, is the relative speed of the remediation program. Injection programs typically range from weeks for small sites of tens of square meters to months for large sites in hectares.

In general, chemical oxidation is not the most cost-efficient approach for treatment of large, low-concentration plumes. Exceptions include situations in which time is an issue or other remediation technologies are not feasible. The duration of a chemical oxidation treatment is often on the order of weeks, in contrast to other technologies for which cleanup duration ranges from months to years.

One of the most cost-effective applications for in-situ chemical
oxidation is DNAPL remediation. Pump-and-treat and other technologies often require years of operation and maintenance and may involve considerable onsite construction. Furthermore, such applications generally reach a threshold, asymptotic level, determined by contaminant sorption to soil particles, pooling on the surface of impermeable layers, vapor pressure and other factors, below which cleanup becomes much less efficient.

On the other hand, asymptotic cleanup levels are not encountered during in-situ chemical oxidation cleanups in which the driving cleanup factor is delivery and contact of reagents with contaminants. Thus, final treatment of sites which do not achieve cleanup objectives is achieved by installing additional injectors or injecting additional reagents to enhance the delivery.

Limitations of treatment

While a number of commercial successes have been logged, there are limitations to in-situ chemical oxidation. Free radical generation by Fenton’s reagent is favored under weakly acidic conditions with pH levels of less than 7, which are achieved by injection of a pH-buffered catalyst solution. Thus an important consideration is the presence of carbonate soil minerals or hard water conditions. Carbonate minerals react vigorously with acids, resulting in higher reagent requirements and in many cases precluding application to limestone aquifers or soils. Dissolved carbonate in water, existing primarily as bicarbonate ion, also reacts with acid and additionally is a free radical trap which also reduces oxidation efficiency. An additional limitation is imposed by the heat and pressure generated during subsurface injections of Fenton’s reagent.

In-situ chemical oxidation may not be suitable for free-product plumes that are within active underground storage tank fields or that surround underground utilities. Very shallow contamination of less than 2 m below grade may not be effectively addressed, because the pressure generated may force injected fluids to short-circuit to the surface rather than diffuse and disperse through the contaminated formation.

The authors of “Final Report for Demonstration of In Situ Oxidation of DNAPL Using the Geo-Cleanse Technology” (Savannah River site case) are K.M. Jerome, B. Riha and B.B. Looney of the Westinghouse Savannah River Company, Aiken, S.C. The authors of “Full-Scale Remediation of Chlorinated Solvents in Clay Soils by In-Situ Chemical Oxidation” (Anniston Depot case) are R.S. Levin and E.M. Kellar of QST Environmental, Gainesville, Fla.; J. Wilson of Geo-Cleanse International Inc.; L. Ware of the Anniston Army Depot, Anniston, Ala.; and J. Findley and J. Baehr of the U.S. Army Corps of Engineers, Mobile, Ala.
GOVERNMENT REFORM LEADS TO NEW REMEDIAL DESIGN PARADIGM

By Andrew Curtis Elmore, Ph.D., and Thomas Graff, P.E.

The federal government is undergoing a revolution with regard to the acquisition of goods and services where best value is replacing low bid as the main selection criteria. The best-value procurement is born of acquisition reform and has lead to a new way of designing remedial actions. The new remedial design promises to be more efficient in terms of effectiveness, cost, timeliness, and public acceptance relative to the exiting state of the practice. The best-value procurement concept is a soup to nuts process which has the potential to benefit both public and private sector restoration processes.

Welcome to the defense acquisition revolution

The genesis of the best-value procurement concept lies in the U.S. Dept. of Defense (DOD) acquisition reform vision to use competitive, negotiated contracting to give the government the best value for its money for national defense programs. The best value concept accounts for tradeoffs between cost and non-cost factors by providing a comparison of factors in addition to cost and price.

The link between the best-value purchase of bullets and bombs by the U.S. Army to the restoration of contaminants at hazardous waste sites is the U.S. Army Corps of Engineers. The Defense Environmental Restoration Program gives the Corps the mandate to address environmental issues at current and former DOD sites. In addition, as the leading federal provider of engineering services, the Corps provides the U.S. Environmental Protection Agency (EPA) with engineering expertise at Superfund-lead sites across the nation.

The personnel of the Hazardous, Toxic and/or Radioactive Waste Branch of the Corps’ Kansas City District are applying acquisition reform concepts to environmental restoration projects by facilitating best-value procurement at all stages of the projects.

The best-value procurement paradigm

The best-value procurement concept for remedial design uses the competitive advantages of our free enterprise system to save the responsible parties time and money while protecting human health and the environment. The heart of the best-value procurement process is performance design specifications which permit potential contractors to propose various remedial technologies. The procurement process includes the comparison of each proposal to a previously defined set of evaluation standards which include specific items related to effectiveness, implementability, and cost.

A review of the current Corps’ remedial design process will establish the context of the best-value procurement definition. Typically, the remedial design process is a four submittal process which mirrors the traditional civil works design process. The four submittals — conceptual design, intermediate design, pre-final design, and final design — each consist of four parts, design analysis report, specifications, plans and cost estimate.

Typically, the Corps or one of their contract architecture or engineering firms prepare the remedial design so that each submittal builds sequentially upon the previous one. This process provides an excellent system of checks and balances so that the quality of the resulting design is very high. The final design package is converted to a solicitation package which is used to competitively acquire the services of a remedial action construction contractor. The remedial design package has usually consisted of prescriptive or quasi-prescriptive specifications which defined the types and
quantities of the required materials as well as the precise assembly or construction methods.

The benefits of the prescriptive specification process are:
- Precise control of the remedial action by the remedial designers.
- Compliance with the expectations of the regulatory agencies such as the EPA.
- Provision of the basis for a competitive bid procurement for the remedial action construction.

A drawback of the traditional remedial process is that restoration technologies, processes, and philosophies are evolving rapidly relative to the time required to complete the four submittal remedial design process and subsequent procurement. Significant technological advances and public acceptance evolution may occur during the typical two-year period necessary to go from initiation of the conceptual design to the initiation of remedial action. During that time, technologies may improve, off-site facilities such as incinerators may close, public acceptance of practices such as landfilling may become negative and innovative technologies may be developed and proven.

The best-value procurement remedial design is a combination of prescriptive and performance specifications. For example, a groundwater pump-and-treat design may include prescriptive specifications regarding the location, flowrate, and construction of groundwater extraction wells and the associated transmission piping while the groundwater treatment element of the action is given in terms of performance specifications.

Those performance specifications would provide a range of assumed groundwater concentrations and flowrates to be treated as well as specifying the quality of the water after the treatment. The firms which respond to the best-value procurement solicitation will propose appropriate treatment processes. In essence, the best-value procurement design may include black box elements which each contractor attempts to define in their proposal. The remedial designers have the final say in the process by assisting in the selection of the remedial action proposal which represents the best combination of treatment effectiveness, cost, implementation schedule and reliability.

These elements can be combined with other factors such as past experience and business management to form a set of source selection factors. These factors are then considered when awarding the cost plus fixed fee type remedial action contract. The cost plus fixed fee contract vehicle is best suited for projects where all aspects of the scope — or remedial design in this case — are not defined in precise detail using prescriptive specifications.

A best-value procurement example for contaminated soil would be a remedial design which prescriptively specifies the quantities and locations of contaminated soil to be excavated, the excavation confirmation criteria, material handling requirements, and backfilling procedures.

Performance specifications would address the acceptable soil concentrations and other required physical parameters after treatment as well as as the disposition of the treated soil. It is conceivable that the firms competing for the remedial action contract could propose a wide range of technologies such as low temperature thermal treatment, composting, biostimulant and ex-situ soil fixing. The design engineers would still evaluate the proposals against the process selection criteria.

**First things first**

If combining prescriptive and performance specifications for major elements of a remedial design seems like a good idea, be warned that a best-value procurement type design is probably not something that a design team can elect to do during the design kickoff meeting. At a Superfund site, consideration of a best-value procurement should begin during the feasibility study phase.

For the pump-and-treat groundwater example, the alternatives which would be analyzed in detail would be differentiated by different pumping objectives such as hydraulic containment alone, hydraulic containment plus limited focused extraction, and aggressive pump-and-treat.

A set of potential groundwater treatment trains could be identified using the technology screening procedure given in the EPA’s RI/FS guidance. The concept is that any of the treatment technologies retained after the screening could be considered during the remedial action. During the feasibility study evaluation of cost, it may be necessary to assume one of the potential treatment technologies as a consistent basis for the evaluation of each alternative.

For example, the following candidates may be retained after the technology screen process: air stripping, activated carbon treatment or advanced oxidation processes. The feasibility study would state any of the three individual processes or combinations of the processes could be used for the remedial action. However, the feasibility study cost evaluation would be performed using the assumption that activated carbon treatment was the only treatment element of each of the alternatives.

Continuing the example, this concept of including a group of technologies as candidates for groundwater treatment would be carried through the identification of the preferred alternative in the proposed plan, the presentation of the preferred alternative to the public during the public comment period, and the selection of the remedial action in the Record of Decision (ROD).

At a contaminated groundwater site in the Midwest, 

Continues on page 14 →
the Kansas City District Corps of Engineers and Woodward-Clyde are following the best-value procurement/remedial design concept. At this site, the ROD selects a pump-and-treat remedial action with a groundwater treatment element defined as follows:

"Treat all extracted groundwater using granular activated carbon (GAC) adsorption, advanced oxidation processes (AOP), and air stripping. GAC adsorption and AOP may be applied individually or in combination, while air stripping must be applied in combination with one of the other technologies..."

This ROD provides the remedial design team the flexibility to pursue a best-value procurement if desired. The three candidate technologies are the result of the feasibility study screening process of all potential technologies. If another category of treatment technology became feasible during the four-year period between the completion of the feasibility study report and the estimated start of the remedial action contractor

Reliance on the competitive proposal process does not relieve the remedial design team from extensive preparations required to prepare the performance specifications and subsequently evaluate the remedial action proposals. prepared by the design team before the procurement process. Such a cost analysis would provide a baseline for comparison of subsequent remedial action proposals. Of course, the technical cost analysis would remain confidential between the design team and the project owner during the procurement process.

What's next?

This new remedial design paradigm acknowledges the changeable technical and public perception conditions facing today's environmental professionals. The paradigm relies on a best-value procurement framework, the heart of which is a set of performance specifications for specific remedial action elements. Preparation for a best-value procurement begins during the development of remedial alternatives and concludes with the implementation of the remedial action. Reliance on the competitive proposal process does not relieve the remedial design team from extensive preparations required to prepare the performance specifications and subsequently evaluate the remedial action proposals.

The discussion of this process has generally been in the context of federal restoration projects; however, the concepts are certainly applicable to other public and private sector projects. The introduction of the best-value procurement process will perhaps stimulate other practitioners to develop, test and share other innovative remedial design processes.
Study reports LUST programs are feeling effects of MTBE releases

By Robert Hitzig, Paul Kostecki and Denise Leonard

MTBE (methyl tertiary-butyl ether) is a fuel additive that has been in use in the United States since 1979 as an octane-enhancing replacement for lead. More recently, MTBE has been used as a fuel oxygenate added to gasoline. The 1990 Clean Air Act Amendments require oxygenates as part of cleaner burning fuels programs. As a fuel oxygenate, MTBE helps reduce carbon monoxide emissions and ozone levels in the nation’s most polluted areas.

Because of these two uses for MTBE, its production has increased steadily throughout the 1980s and 1990s. Currently, MTBE production exceeds 8,000 million kg per year; it is the most common fuel oxygenate used to reduce air pollution.

Leaking underground storage tanks (LUST) have been a significant source of groundwater contamination for many years. Since 1988, state UST programs have reported about 360,000 petroleum releases to the US EPA’s Office of Underground Storage Tanks. Although the rate of new releases is declining due to implementation of federal and state UST programs, the huge number of federally regulated USTs, about 2.1 million in 1988, has resulted in a significant adjustment period to making good tank management common practice.

When significant concentrations of MTBE (>20 ppb) are present in groundwater, it is an indicator of a petroleum release that requires investigation. Typically the release is from an UST, but other potential sources include aboveground storage tanks and pipelines. Gasoline releases that contain MTBE present unique remediation concerns because MTBE is much more soluble in water than benzene, toluene, ethylbenzene and xylene(s) (BTEX), does not adsorb to soil particles as readily as BTEX, moves at almost the same speed as groundwater and has much lower biodegradation rates than BTEX.

As a result, MTBE groundwater plumes can be much larger than the remaining gasoline constituents. This characteristic resulted in MTBE contamination being elevated to a national level in 1996 when two Santa Monica, Calif., drinking water well fields were shut down, at a cost of millions of dollars a year, because of high MTBE concentrations.

In addition, although MTBE is know to be less toxic than many gasoline constituents, including benzene, it also has a much lower taste and odor threshold. Relatively low levels can make a drinking water supply unpotable. The December 1997 EPA document continues on page 16 →

Robert Hitzig is an environmental scientist in the US EPA Office of Underground Storage Tanks, Washington D.C. Paul Kostecki is an associate professor and Denise Leonard is a research fellow at the University of Massachusetts, Amherst.
entitled Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Methyl tertiary-Butyl Ether recommends MTBE concentrations of 20 to 40 ppb as a level that would likely avoid unpleasant taste and odor effects for a large majority of people.

Furthermore, because MTBE has a greater tendency to stay in water than BTEX, it can be more difficult and expensive to remediate groundwater when MTBE is present as compared to a site that just contains BTEX.

Survey goals and methods
As a result of these concerns about MTBE contamination and remediation, the University of Massachusetts, support by the U.S. EPA's Office of Underground Storage Tanks (OUST), devised a study to gauge the impact of MTBE on state LUST programs and to determine and evaluate any effective methods for dealing with MTBE that states have developed.

Because obtaining very specific data from state programs would be too burdensome and would dramatically reduce the response rate, the survey was designed to allow respondents to choose a general response, typically from five choices, that would not require an intensive search of existing files and data.

The survey was peer reviewed by several industry experts then beta tested by six state LUST program representatives. After edits were incorporated, a final version was mailed to all 50 state LUST programs and the District of Columbia. If no responses were received within four weeks, a follow-up phone call was made. The resulting data include responses from 49 LUST programs. Only California and Indiana have not responded.

Rates of MTBE detection
The survey indicated that 27 states require analysis for MTBE and another eight states request or receive MTBE data more than 20 percent of the time. About 25 percent of LUST programs (14 out of 49) did not appear to have sufficient data on the presence of MTBE in their jurisdiction to answer many of the questions in this survey. Of the states that acquire MTBE data, the majority (27 of 34) indicated that MTBE was present more than 20 percent of the time. Almost one third report MTBE present at more than 80 percent of their LUST sites. See figure 1, page 15.

Numbers of contaminated wells
LUST programs were also asked to estimate the numbers of MTBE-contaminated drinking water wells reported in their territory. Of all the LUST programs, 25 have had reports of private drinking water wells contaminated with MTBE. See figure 2, this page. The total number of contaminated private wells was estimated to range from 2256 to 2663 with the largest number of contaminated wells reported by one program at 400. States reporting private well
contamination included all areas of the country and appeared to be a random distribution.

Nineteen LUST programs reported knowing of public drinking water wells contaminated with MTBE. The total number of contaminated public wells was estimated to range from 251 to 422; the largest number reported by one program was 65. Although very few data were received on the actual MTBE concentrations, preliminary indications are that the vast majority of the public drinking water well detections is below 10 ppb. Although some midwestern and western states reported public well contamination, most of the contaminated public wells were concentrated in eastern states.

**MTBE detections with no identified source**

A number of LUST programs had previously reported significant levels of MTBE contamination at sites where no release could be detected, often with very high levels of MTBE and an absence or very low levels of other gasoline constituents. This survey hoped to shed some light on the source of these mysterious MTBE releases. Twenty states reported having at least one site where MTBE was detected but no release was documented. The survey indicated there may be about 300 of these mysterious MTBE sites around the country.

No particular type of tank or piping was associated with the releases, so compatibility problems with UST system materials did not appear to be a factor. States did, however, offer other explanations. These possibilities included surface dumping of gasoline, such as from a lawn mower, unassociated with the UST facility, historic releases at a facility with new tanks, leaking overfill catch basins, and seepage into monitoring wells.

Other possible explanations from some of these sites may be a leak in the vapor recovery systems or incorrect results from tank and piping tightness tests.

Although MTBE may be the only gasoline constituent detected at some of these sites, there is no evidence that MTBE is the only compound being released. All indications are that gasoline is being released but that MTBE with its high mobility is the first compound to reach the point of detection.

**Is MTBE present in non-gasoline petroleum products?**

Five states reported detecting MTBE at concentrations greater than 20 ppb in releases of five different types of non-gasoline petroleum: diesel fuel, jet fuel, heating oil, aviation fuel and waste oil. Although petroleum industry representatives state that MTBE is not added to these products at the refinery, it appears they may pick up MTBE in the distribution system.

*Continues on page 18 →*
Study, from page 17

For example, a pipeline may carry gasoline with MTBE one day and diesel fuel the next. Residual MTBE may then be mixed with the diesel fuel. In the same way, fuel trucks or barges may contain residual fuel that can be mixed with another product. As a result it may be necessary to perform analysis for MTBE at all petroleum releases, not just gasoline sites.

MTBE remediation

Because of its high solubility, high mobility and low biodegradation rate, MTBE can reach drinking water wells more quickly than other gasoline constituents. As such, it also increases the number of incidents where remediation activities will be focused primarily on the task of removing MTBE from groundwater. Figure 3, page 17, shows the degree to which MTBE drives cleanup activities in states that use reformulated gasoline (RFG) and in states that do not use RFG.

RFG is gasoline used year-round in ozone non-attainment areas. MTBE is often added to this gasoline at a concentration of 11 percent by volume. In other areas, MTBE is most often added to gasoline for octane-enhancement purposes only, typically at concentrations below 8 percent by volume. As would be expected, RFG areas which use a higher concentration of MTBE have more sites in which MTBE is the primary remediation concern. In non-RFG states, MTBE appears to be only rarely the major reason for remediation activities. See figure 4, page 17.

LUST states were also asked if they could qualitatively rate the level of success they had in removing MTBE with various soil and groundwater remediation methods. In general, existing technologies were rated as successful. Figure 5, this page, presents soil treatment methods and the number of LUST programs that rated each method in the various categories. Figure 6, this page, presents the number of LUST programs rating each of the groundwater remediation technologies.

As would be expected because of MTBE’s recalcitrance, technologies that relied on biodegradation of MTBE were generally rated less successful than other methods. It is also not

<table>
<thead>
<tr>
<th>Technology</th>
<th>Successful</th>
<th>Unsuccessful</th>
<th>Mixed success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Vapor Extraction</td>
<td>14</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Low temperature</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>thermal desorption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biodegradation</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Excavation</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>O2 Injection</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: These numbers reflect the number of LUST programs responding in this way.

Figure 5. What soil remediation technologies are working?

<table>
<thead>
<tr>
<th>Technology</th>
<th>Successful</th>
<th>Unsuccessful</th>
<th>Mixed success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump and treat</td>
<td>10</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Air Sparging</td>
<td>15</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Biosparging</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Bioreactor</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Natural Attenuation</td>
<td>9</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Dual Phase Extraction</td>
<td>8</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 6. What groundwater remediation technologies are working?

Figure 7. Incremental cost increase of MTBE remediation.
surprising that soil vapor extraction rates very highly because MTBE's high vapor pressure and low attenuation rate actually make it easier to remove from soil than by BTEX. Fourteen programs rated SVE "successful" and none rated it "unsuccessful."

Groundwater remediation methods were rated as generally successful by LUST programs. Air sparging, in particular, was rated as "successful" by 15 LUST programs with no programs rating it "unsuccessful." Although these data are very qualitative and imprecise, they do imply that existing technologies may be effective in remediating MTBE contaminated soil and groundwater.

**Incremental cost increase of MTBE contamination**

One of the most difficult impacts of MTBE contamination to quantify is the incremental cost increase of remediating MTBE in gasoline versus its absence. Although most states do not have any data to support an answer, state staff experiences with managing different types of sites can be useful in providing estimates and establishing trends.

As would be expected, states that have areas using RFG, and therefore have higher concentrations of MTBE, are more likely to have MTBE significantly increase the cost of remediation. See figure 7, page 18. LUST programs report that about 70 percent of sites in non-RFG states will experience no cost increase due to the presence of MTBE. However, LUST programs in RFG states estimated that about 40 percent of sites experience at least a 20 percent cost increase due to the presence of MTBE.

**What it all means**

The addition of MTBE to gasoline has, for many years, helped to reduced many harmful air pollutants. However, because of its high mobility in soil and groundwater, when gasoline is released the detection of MTBE may be the first indication of a problem. As a result, some state LUST programs have been dealing with MTBE remediation since the beginning of its use in the early 1980s.

This study indicates that MTBE detections by most state programs is common and that because of different behavioral characteristics of MTBE from BTEX, MTBE may contaminate groundwater in unexpected locations and in unexpected ways, such as at diesel fuel sites or from surface dumping of small amounts of gasoline.

Consequently, this study indicates that state LUST programs should be conscious of the potential for MTBE contamination when investigating all kinds of petroleum releases, anywhere in the United States, regardless of whether reformulated gasoline is used in the area of investigation.

LUST programs have also reported that existing remediation technologies for both soil and groundwater can be successful in removing MTBE from the subsurface. This data also indicates that releases of gasoline containing MTBE can significantly increase the cost of remediation, particularly when it contains high concentrations of this fuel additive. Although most MTBE contaminated sites do not seem to cause excessive or even significant problems for most LUST programs, for a few a number of costly sites have resulted.

The problems associated with gasoline releases from USTs, such as the potential for significant drinking water well contamination, reinforces the need for strict enforcement of both federal and state UST upgrade, replacement and closure requirements. On Dec. 22, 1998, all USTs will be required to meet federal standards. Compliance and enforcement of these regulations should minimize the numbers and sizes of additional petroleum releases and prevent MTBE from causing significant impacts on drinking water supplies.
Closing the deal

Deal structure can affect risk and liability and your ability to close

Brownfields projects fundamentally are development deals. Without a development deal that closes, brownfields mean nothing. Closing the deal is critical, and allocation of risk is one of the key factors involved in closing a deal. Issues involved in allocating risk and liability in brownfields transactions must be viewed from several perspectives:

- contractual allocation of risk between parties;
- protections offered by government;
- insurance protections, and;
- special brownfield programs.

As with other transactions involving contaminated properties, once the initial determination is made that the risk associated with the environmental issues will not preclude the transaction, the focus is on packaging the environmental issues so that financing can be obtained and ensuring the buyer has an effective and realistic exit strategy.

What are brownfields?

Brownfields mean different things to different people. In general, brownfields refers to abandoned, inactive or underused industrial or commercial sites, usually located in urban areas, affected by either real or perceived environmental contamination.

At one end of the spectrum, a brownfields project can involve an effort to team the developer, consultant, community and government to redevelop an underused area by using environmental issues as leverage. At the other end of the spectrum, brownfields simply can involve a buyer purchasing contaminated property at a significant discount, cleaning up the property cost-effectively, and selling it at a profit. For the purposes of this discussion, the former is considered a brownfields transaction; the latter is viewed more as a traditional real estate deal involving a contaminated property.

There may be as many as 425,000 brownfields properties in the United States. These properties often are avoided because of fear of environmental liability. However, the advent of various private and government initiatives to mitigate environmental liability and risk, combined with a robust real estate market, has rekindled interest.

Brownfields development and community support

A fundamental aspect of a brownfields development project, and one that differentiates it from more traditional real estate development projects, is the need to gain community support for the proposed development plan. Significant brownfields projects generally require early and substantial involvement of the community to gain the full benefits of the brownfields component of the project.

By Stephen C. Jones, Abhi-Shék Jain and Anoop G. Shroff

Stephen C. Jones is a partner, and Abhi-Shék Jain and Anoop G. Shroff are associates with Jones, Day, Reavis & Pogue, Washington, D.C.
Specifically, garnering early support from the community can strengthen the purchaser’s or developer’s ability to negotiate a reasonable and cost-effective resolution of environmental issues on the property. This includes ensuring both a cost-effective remediation and an effective mechanism for terminating or at least managing risk of liability.

The leverage of meaningful community support gives the developer more flexibility in negotiating with environmental and other agencies. For example, the developer can negotiate for the application of more aggressive risk-based cleanup standards. This flexibility comes from the presumed willingness of the community to accept a more reasonable and cost-effective cleanup — a cleanup that is fully protective of human health and the environment, but is less than cleanup to background or precontamination levels — to enjoy the economic benefits that the project will bring to the community. To the extent that environmental regulatory agencies will face community pressure to facilitate the project, there may be better opportunities to use risk minimization and, ultimately, a better chance for a cost-effective and successful brownfields project.

Among the parties: mechanisms for contractual risk allocation

Risk minimization begins with contractual allocation of risk among the buyer, seller and lender. In a brownfields project, contractual risk allocation mechanisms are of paramount importance because the transaction frequently hinges on whether the parties — buyer, seller or lender — are sufficiently comfortable with the share of risk that is being allocated to them. In general, the contractual risk allocation process follows, and is heavily influenced by, the environmental risk assessment and related due diligence conducted for the property.

Although not normally considered a risk allocation method, strategic environmental due diligence, such as a Phase I or Phase II environmental assessment, is a fundamental prerequisite in most cases to an effective allocation of liability. Depending on how thorough the due diligence process is, and how the findings of the due diligence are reflected in written reports, both real and perceived risk can be assessed and allocated to meet the risk profiles of the various parties. Care should be taken to strategically guide the due diligence process, taking into consideration purchaser liability issues, potential future

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<thead>
<tr>
<th>Absorbency Power</th>
<th>Size/Weight</th>
<th>Oil Absorbed</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAMSORB-1</td>
<td>30lb/bag</td>
<td>16 to 24 gal.</td>
</tr>
<tr>
<td>RAMSORB-2</td>
<td>20lb/bag</td>
<td>20 to 30 gal.</td>
</tr>
<tr>
<td>Floor Sweep</td>
<td>30lb/bag</td>
<td>15 to 22 gal.</td>
</tr>
<tr>
<td>Boom</td>
<td>5” x 10’</td>
<td>5 to 8 gal.</td>
</tr>
<tr>
<td>Sock</td>
<td>4” x 4’</td>
<td>1.5 to 2 gal.</td>
</tr>
<tr>
<td>Pad</td>
<td>18” x 18”</td>
<td>30 to 40 gal./package</td>
</tr>
</tbody>
</table>

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negotiation leverage in cleanup negotiations with regulatory agencies and future exit strategies.

Representations and warranties, guarantees, as-is clause
Representations, warranties and guarantees enable the parties to set forth, in the purchase agreement, information about the present environmental condition of the property. Representations and warranties serve several purposes. By delineating the environmental condition of the property at the time of the transaction, a baseline is created from which future, unknown environmental conditions can be assessed.

The process of negotiating and completing representations and warranties also can be an effective due diligence or discovery tool for a buyer, forcing the seller to address and provide some form of disclosure regarding each issue raised in the representations and warranties. Finally, from the buyer's perspective, the seller's representations and warranties perform an important risk allocation role; they can provide a form of guarantee and, if not correct or complete, can trigger the indemnification provisions in a purchase agreement and often can form the basis for a lawsuit for recovery of damages flowing from the breach.

Representations and warranties also can be a useful risk allocation mechanism because they enable the parties to remove specified potential environmental liabilities from consideration. For example, a seller might represent that no hazardous wastes have been treated, stored, or disposed of at the property or that all necessary environmental permits for the property have been obtained.

However, although this may provide comfort to a buyer, particularly if breach of the representation triggers an indemnification obligation, it is generally prudent for a buyer to at least check representations and warranties with independent due diligence.

Since a seller's representations and warranties can be the basis of liability against the seller, the seller generally will attempt to qualify these statements by limiting them in some way, such as to the seller's actual knowledge, to the seller's period of ownership or to some manner of materiality. Representations and warranties also can be qualified by limiting the survivability of these statements to a specified time period. The appropriate balance between the buyer's usual desire for absolute, unlimited representations and warranties, and the seller's desire to limit them as much as possible, will depend on negotiation, the circumstances of the property, the environmental conditions of the property, and numerous business and other factors in the deal.

An as-is clause is the functional opposite of a seller's representations and warranties. It informs the buyer that the seller makes no representation as to the environmental conditions of the property and therefore assumes no responsibility for disclosure of conditions. This shifts the due diligence burden and, usually, liability for environmental conditions entirely to the buyer.

But, given the recent proclivity of courts to question the doctrine of caveat emptor, or buyer beware, and the proliferation of state statutes and common law doctrines requiring disclosure of known environmental conditions — particularly latent defects, the utility of the as-is clause is somewhat diminished. Nevertheless, courts generally have enforced as-is clauses if they are specific and detailed. The as-is clause thus can serve an important role in contractual risk allocation, particularly when used in conjunction with mechanisms such as releases and indemnifications.

Releases and exclusive remedy provision
A release is a contractual risk allocation mechanism that relieves a party of liability it might face. For example, if contamination is identified on a property and if it can be quantified such that a reasonably definitive remediation cost estimate can be determined by the consultant, it would not be unusual for the seller to assume responsibility for the cleanup up to the estimated cost and possibly a contingency amount, and for the buyer to release and sometimes also indemnify the seller for any costs that may exceed the estimate.

Further, if the seller agrees to conduct the post-sale remediation, in addition to simply paying for it, the buyer might release the seller from and against economic damages such as lost profits resulting from interruptions caused by the seller's remediation activities. Of course, great care must be exercised in drafting the scope of a release clause to avoid unintended allocations of liability and, if post-closing access by the seller is involved, attention must be given to appropriate access and indemnity agreements that will protect both the buyer and the seller.

Exclusive remedies provisions are the functional equivalent of release clauses, but approach the issue from a different perspective. An exclusive remedies provision provides that any remedies available to a party are limited to those set forth in the contract. For example, if a seller provides a buyer an indemnity with respect to certain kinds of on-site contamination, the seller may want to include an exclusive remedies provision that limits the buyer's recourse against the seller for such contamination to that contractual indemnity and thereby preclude recovery on possible common law or statutory theories of recovery.

Reopener provisions, which are not uncommonly used to address environmental liabilities, can operate to undo a release or other such provision if certain conditions come to pass. The most common relates to an agreement to release a seller from certain liabilities if new and unexpected contaminants are found, if site conditions
differ significantly from those contemplated by the parties, or if the cost of remediation exceeds a predetermined amount of money.

**Indemnification provision**

In most transactions involving contaminated properties, including brownfields projects, the most important contractual risk allocation mechanism between the parties is the indemnification and hold harmless provision. Indemnities hold this distinction because they typically address the allocation of unknown, future environmental liabilities — the liabilities that usually engender the greatest anxiety on the part of buyers, investors, and lenders.

Indemnification clauses generally require one party to compensate and often defend the other party from and against certain, specified liabilities sustained or incurred by the indemnitee. For example, the seller might indemnify the buyer from and against any remediation costs or losses resulting from groundwater contaminated by perchloroethylene, a substance that was used by the seller or one of the seller’s tenants in a dry cleaning store.

The indemnification parameters are of critical importance: the scope of the indemnity, the duration and the monetary limits, among others. Buyers generally strive to obtain the broadest indemnification possible from the seller; of course, sellers strive to limit the indemnity as much as possible.

No matter how favorable the language in an indemnity is, however, it will always have one significant, overriding limitation: The indemnity is only as good as the financial condition of the indemnitor. Consequently, unless the indemnitor has substantial financial resources, the indemnitee should consider buttressing or backing up the indemnity with a holdback, escrow account, letter of credit, insurance or other financial support mechanism.

**Other contractual provisions related to remediation**

In brownfields projects, allocation of the risks associated with remediation of the property is critical since remediation can be expected to be a relatively lengthy, complicated process. After a remediation plan is formulated, both buyer and seller must decide what additional contractual mechanisms they want to employ to allocate risk.

Assuming the seller will conduct the remediation, these mechanisms should address: seller’s continued access to the property and the buyer’s duty to cooperate with remediation efforts; buyer’s right to contact or participate in meetings with regulators; buyer’s right to review and

Continues on page 24

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approve workplans, remediation procedures or results, and reports; buyer’s requirement that the seller obtain closure and a sign-off letter from the regulatory agency; buyer’s right to provide input regarding cleanup standards; and selection of dispute resolution mechanisms.

Contractual mechanisms should be integrated and combined for maximum benefit

Selection of the most appropriate combination of these contractual risk allocation mechanisms requires a thorough understanding of the legal and practical consequences of each type of mechanism and a transaction-specific analysis of the environmental risks posed by the property, the terms of the deal, and the relative risk tolerances and business objectives of the buyer and seller.

The blind use of form provisions — particularly indemnification provisions — can be dangerous. What will protect a buyer in one instance may not address the buyer’s issues in a second transaction, and certainly will not satisfy the requirements of a seller in another.

The not-so-secret message of brownfields projects is the recognition that environmental issues are no longer — and never really should have been — the black box issue always requiring knee-jerk, expensive responses. Environmental issues simply should be another item on the due diligence checklist that must be addressed by the parties to a transaction and, most importantly, one which can be analyzed, negotiated, and resolved, and for which the risk can be evaluated. Careful thought must be given to structuring and documenting these deals if full protection is to be obtained, and full advantage is to be gained, with respect to environmental matters.

Protections offered by regulatory agencies

Relatively early on, the U.S. Environmental Protection Agency (EPA) recognized that substantial barriers confronted developers of brownfields properties and that these barriers would have to be removed or, at a minimum, lowered and made manageable if significant brownfields development was to occur. Following the lead of several states, in 1995 EPA promulgated various programs and policies designed to spur efforts to develop brownfields properties under its Brownfields Action Agenda. Among other things, EPA’s Brownfields Action Agenda provides for prospective purchaser agreements, comfort letters, and release from potential groundwater contamination liability.

In the context of private brownfields development efforts, the tools provided or endorsed by the government that seem to have the most potential use are as follows:

**Prospective Purchaser Agreements.** EPA recognizes that CERCLA liability and, equally important, the threat of such liability, stands as a significant barrier to the purchase and redevelopment of brownfields properties. To remove or minimize this barrier, EPA and the U.S. Dept. of Justice (DOJ) have developed a policy to enter into agreements with prospective purchasers of brownfields properties in which the EPA promises not to sue the purchaser for existing contamination and to provide certain protections against third party suits in exchange for adequate consideration, such as monetary payment.

Under this policy, several criteria must be satisfied before the EPA will enter such an agreement.

- EPA action at the site must have been taken, be ongoing, or be anticipated.
- EPA should receive a direct benefit in the form of a cleanup or there should be an indirect benefit to the public, such as jobs.
- New site development should not contribute to existing contamination or interfere with EPA’s response actions.
- The new development must not pose health risks to the community or to persons at the site.
- The prospective purchaser must be financially viable.

EPA has already entered into more than 60 agreements with prospective purchasers nationwide. Although not expressly required by the policy, EPA and DOJ in most cases also have required payment of a fee to enter a prospective purchaser agreement. This fee can be significant and should be considered and included as part of the negotiations in any transaction.

Before initiating discussions to obtain a prospective purchase agreement, it is important to understand that the agencies approach them as enforcement issues first, and development deals second. The clearest manifestations of this are the fee that will be assessed and the enforcement attitude, as opposed to a deal-making attitude, that still permeates the process.

**Comfort letters.** EPA will offer prospective developers of brownfields properties an informational comfort letter intended to provide the developer with a better understanding of EPA’s future course of enforcement action with respect to the property. EPA reiterates that these letters do not constitute an assurance of no further action by EPA, but depending on the circumstances such letters may still be useful.

**Groundwater contamination policy.** EPA has a policy against taking enforcement action for groundwater contamination against the property owner if the contamination is solely the result of subsurface migration of hazardous substances from a source outside the property. This long-standing informal policy was formally adopted by EPA in 1995, and also appears to be the policy in most states.

Although only policy or guidance, and not a legally enforceable release from the CERCLA liability that
technically attaches to any property that overlies contaminated groundwater, the groundwater contamination policy can provide significant comfort and seems to have been accepted in the market as an effective limitation on liability. As a result, the focus of due diligence in areas with offsite or even regional groundwater contamination problems is to verify and confirm that the subject property is not a source of contaminants to groundwater and that the property itself has not contributed to the groundwater contamination. Effective documentation of these findings, particularly if it can be combined with some form of confirmation from the regulatory agency, can provide effective comfort to lenders and prospective purchasers.

Federal and state lender liability rules. To protect secured lenders from environmental cleanup liabilities, Congress passed legislation in 1996 that amended CERCLA and the Resource Conservation and Recovery Act (RCRA). These amendments set forth guidelines regarding the extent to which a secured lender can be involved in the environmental compliance and overall management of a property without incurring liability under CERCLA as an owner or operator, or liability under RCRA as an owner of an underground storage tank. Moreover, the amendments enable lenders to foreclose on a property without automatically assuming owner/operator liability under CERCLA. Several states have adopted similar rules excluding secured lenders from liability under their state Superfund statutes. By offering the lenders involved in a brownfields project an additional degree of comfort, these rules facilitate the financing of brownfields projects.

State programs. The states have adopted a wide variety of government-initiated programs and mechanisms designed to provide comfort to buyers, lenders, and investors and to facilitate transactions. The groundwater containment zone legislation in California, which allows certain areas affected by groundwater contamination to be designated as contained and not subject to cleanup, is one example.

Environmental insurance

Environmental liability transfer insurance policies have been available in the real estate context for a number of years. Only in the last few years, however, has the scope of coverage been expanded, and the premium price reduced, to levels that can make these policies effective and important components in the packaging of contaminated properties.

The amount of coverage, the deductible, the terms, and the premium all are negotiable and, as with most issues in a brownfields transaction, careful thought must be given to the circumstances and the objectives of the parties. The terms of the transaction and, of course, the circumstances of the property can affect coverage, and coverage effective in one situation is not necessarily appropriate for the next deal.

Although insurance seems to have been accepted by most in the marketplace, it is still viewed with some suspicion and and its long-term value is uncertain to many. The claims history under these policies is very limited and, thus, it is not clear how the insurers will handle claims under these policies if claims begin to mount.

The question, of course, is whether the insurance monies will be there when needed, due to either the refusal or inability of the companies to pay, and thus how comfortable investors and purchasers should be in relying on it. This concern is less important if insurance is used as supplemental protection following due diligence. However, more and more purchasers, investors, lenders, and others appear to be looking to insurance as a substitute for comprehensive due diligence. As reliance on insurance as a primary source of protection grows, the risks inherent in insurance increase as well.

Careful consideration of the foregoing contractual risk allocation mechanisms, strategic due diligence, and prudent use of environmental insurance can make the difference between closing or losing a brownfields deal. A thorough understanding of the legal and practical consequences of each mechanism and their creative application to the unique circumstances of each deal, is fundamental to the success of brownfields projects.

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Eye on ECOS

Environmental justice guidance lacks any definitive guidelines

By William Kucharski

Eye on ECOS is a column that is designed to provide up to date information on the states. This issue’s article concerns environmental justice, a topic that is of utmost importance to anyone who has any responsibility for permitting or plant location selection. In 1994, as Secretary of the Louisiana DEQ, I wrote the first permitting decision in the country that directly addressed environmental justice issues. I stated in that decision that there were no relevant or consistent standards by which to measure environmental justice nor was there any definition as to what environmental injustice meant.

It is four years later and we are no closer to having these definitions today than we were when I wrote my decision. Comments on this article and on the topic itself are welcomed. There is a long road ahead of us upon which many, many intense debates will have to occur before this issue will be settled.

William Kucharski is former Secretary of the Louisiana Department of Environmental Quality. He can be reached at WKUCH154@aol.com. Robert E. Roberts is the executive director of ECOS. Molly Conrecode is editor of ECOSTates. Carol Leftwich is project manager for several ECOS projects.

By Robert E. Roberts, Molly Conrecode, and Carol Leftwich

In the past year, the two most important movements in the second half of the 20th Century have come into confluence in a potential conflict that is less about environmental protection and civil rights than it is about federal mandates, the rights of state and local governments to govern, and determining who is to decide environmental issues. The unfortunate losers in this contest may be the minority communities although the program is designed for their protection.

Organizations in communities near industries became alarmed that their communities might be exposed to a disproportionate and dangerous amount of pollution associated with the industries. These groups, often aided by environmental or legal groups, filed suits or complaints under Title VI of the 1964 Civil Rights Act which outlaws discrimination under any program or activity receiving federal financial assistance.

As state environmental agencies receive federal monies to implement EPA regulations, and as those state agencies often make the permitting decisions which allow industries to operate, the complaints or suits were directed toward the environmental agencies, alleging that the agencies had been guilty of discrimination.

There was almost always no evidence that such decisions were intentionally discriminatory. States work to make permitting decisions based only on the facts presented. Nonetheless, there was a feeling of environmental and civil rights violations. After the number of complaints reached a substantial number, EPA issued Interim Guidance for Investigating Title VI Violation Complaints Challenging Permits.
Reactions to the Guidance

Reaction to the Guidance has been almost uniformly negative. The National Association of Black County Officials (NABCO) opposed the Guidance in April. The letter from NABCO stated: “The Guidance as proposed is punitive to local governments and does not facilitate the continued growth of community-level participation in environmental protection.”

The National Association of Counties had already taken a strong position regarding what they see as a local issue, and they reiterated that position in May in a letter to the EPA. Two days later, 14 State Attorneys General went on record with their concerns about the Guidance. Late in June, the United States Conference of Mayors passed a resolution also asking that the Guidance be suspended.

ECOS first raised the issue with EPA in February 5 letter to EPA Administrator Carol Browner asking that states be extended the maximum opportunity to help draft the document, and that EPA not promulgate, implement or rely upon draft guidance until the states could become involved. ECOS has established a workgroup to address these issues with the Guidance and the broader subject of environmental justice. This workgroup is headed by Russ Harding, director of the Michigan Dept. of Environmental Quality.

On March 26, at the spring meeting in New Orleans, ECOS passed a resolution which, among other things, calls upon EPA to withdraw the Guidance until outstanding issues can be worked through. Five state commissioner have been appointed to the Title VI Implementation advisory committee. They are: Harding; Robert Shinn, commissioner of the N.J. Dept. of Environmental Protection and president of ECOS; Jane Nishida, secretary of the Maryland Dept. of Environment; Lang Marsh, director of the Oregon Dept. of Environmental Quality; and Barry McBe, commissioner of the Texas Natural Resource and Conservation Commission.

The group is to make recommendations to Browner before the end of the calendar year. ECOS also has a representative on the National Environmental Justice Advisory Committee. Addressing many of these same issue, ECOS has also established a location on its homepage — www.sso.org/ECOS — to post the environmental justice policies of various states.

On June 18, 34 state commissioners signed a letter to Browner offering to help meet the environmental justice demands inherent in all of their positions. Two more commissioners joined the letter later to bring the total to 36. Under development are a workshop for states to share ideas about state environmental justice programs and a conference next year to address the recommendations made by the Title VI committee.

Continues on page 28 ->

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Problems with the Guidance

Why has the reaction to EPA’s efforts been so negative? Unfortunately, the Guidance doesn’t provide much guidance. It states that actions that result in a discriminatory effect violate Title VI and that EPA “will determine whether the permit at issue will create a disparate impact or add to an existing disparate impact on a racial or ethnic population.”

Disparate impact is not defined, nor are there any indicators for measuring it. No procedure is suggested for measuring a cumulative impact or what that phrase might mean. No guidance is given on how to assign responsibility for impacts from a variety of sources.

Assume, for example, a location exists with four facilities making discharges to the air. One is new and needs a permit. One needs a permit renewal. One needs a permit modification not related to discharge. One is fully permitted. Assume further that, through a procedure not yet specified, this cumulative impact which is not as yet defined is found by EPA to be disparate. Whose permit gets denied?

Equally important, the Guidance does not consider the geographic parameter of disparate impact. How does one define the disparate impact-shed? Do the environmental risks have to be borne by the community immediately surrounding the facility? Or are impacts measured that may take place much further away?

A more subtle failing of the Guidance is the lack of suggested solutions when the local minority community has, through a democratic process, supported a facility only to have it stopped by groups from outside the community or, perhaps, from outside the state. To whom must the state environmental department and EPA listen?

The Guidance discusses that disparate impact arguments can be made for any number of environmental impacts stemming from any media in a facility. Does this mean that separate consideration must be made for every potential risk? The reporting and permitting required by this rule might pose a heavy burden on both the regulator and the regulated community.

The document also suggests that the burden of proof — or disproof — is on the state. Once there is an initial finding of disparate impact, the burden of proof shifts to the state to disprove, justify or mitigate rather than resting on the complainant to show harm. In fact, no health harm is required to be shown, nor are there any ways indicated to justify or mitigate the impact, though both are addressed as possibilities in the Guidance.

Major deficiencies in the Guidance

While all of these issues are important, four potential impacts seem most critical.

- The system may encourage industrialization in greenfields because such an action may avoid the issue of cumulative impact and may lack minority communities to raise the issue. This may increase environmental damage rather than reduce it. Such development is also inconsistent with newly established growth management or sustainable development programs, as it encourages industries to move out of central urban areas to cleaner, greener spaces.

- The system may discourage redevelopment of brownfields because it does not encourage industries to occupy space where other facilities reside or where urban areas are searching for economic redevelopment through increased tax base and employment opportunities. These areas tend to be located in urban centers and tend to have large minority populations. In other words, two programs designed by EPA to improve the lot of minority groups appear to be in direct opposition.

- The system may encourage industrial flight offshore where businesses won’t be burdened with repetitive permitting. This would not only undermine economic development in our states, but it might add to global environmental problems if offshore facilities do not maintain the same standards required by U.S. jurisdictions.

- The system unnecessarily affects the division of governmental responsibilities among local government, states and the federal government. Local zoning and land use decisions are local government decisions. The Guidance suggests a federal permitting system for environmental justice compliance. For example, a local zoning decision establishes an industrial zone. The state approves a permit for a facility to be built in the locally designated industrial zone only to have the federal environmental agency overrule that decision.

ECOS does not have a lack of interest in equal treatment. Rather, ECOS members believe state environmental agencies are probably more sensitive to the issues of fair treatment that serve as a basis for environmental justice than the EPA is if for no other reason than that state agencies are generally more accessible to people with complaints than a federal agency.

If people do not like actions taken by their state agencies, their redress of grievances runs directly through their state legislative representative to the agency’s budget and procedures and through the voting booth to the agency’s ultimate boss — the governor.

However, guidance which is not thought through, which is contrary to other efforts to help disadvantaged groups, and which cannot be administered does not help anybody or anything — not the regulator, not the regulated community, not the protected community and not the environment.
Weathering affects petroleum ID

By Kevin J. McCarthy, Allen D. Uhler, and Scott A. Stout

This column has previously discussed the basic physical and chemical properties of common petroleum products and the features of these materials that can be used to classify and identify petroleum in environmental samples using gas chromatographic methods such as Modified EPA 8015. Fresh petroleum, with all the major chemical constituents present and not suffering from any alteration due to environmental exposure, contains the distinguishing chromatographic properties most readily used to classify the materials.

In many cases, petroleum encountered in a site investigation has been chemically altered due to environmental exposure, and its properties change — sometimes radically — resulting in a gas chromatographic trace with little resemblance to the unaltered product. To the untrained eye, these altered GC traces can be misinterpreted, leading to the wrong conclusions about source, transport and fate of petroleum in the study area.

Occasionally, samples collected from a site contain petroleum products or related wastes that have remained chemically intact since the time of release. Using well established laboratory and gas chromatographic techniques, a laboratory analyst with reasonable experience can usually identify the petroleum present in such samples.

This scenario is often atypical. More likely is a situation where the fugitive petroleum under investigation has been involved in one or more complex interactions with physical, chemical, or biological processes that alter the composition — and hence chromatographic features — of the material. "Weathering" is the term commonly used to describe the effects of these processes.

Weathering processes affect the different classes of hydrocarbons that comprise petroleum. To understand the weathering processes, it is helpful to recall what petroleum is composed of, because weathering processes can affect each of these chemical classes somewhat differently. Most petroleum products are predominantly aliphatic and aromatic hydrocarbon compounds. These compounds range from C_3 through C_{40}, depending on the nature of the material. For example, a crude may contain C_3 through C_{40} while a diesel fuel will only have compounds in the C_6 through C_{24} range.

The aliphatic compounds include straight chain or n-alkanes, branched-chain which includes iso-alkanes or isoprenoids, and cyclic aliphatic compounds, while the aromatic hydrocarbon compounds include monoaromatics such as BTEX and polycyclic aromatic compounds such as PAH and their various alkylated.

Continues on page 30

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Kevin J. McCarthy, Allen D. Uhler, Ph.D., and Scott A. Stout, Ph.D., are research scientists and consultants with Battelle’s Environmental Forensics Investigation Group, Duxbury, Mass. Uhler is also a member of the Soil & Groundwater Cleanup Scientific Advisory Board.

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homologues, including aromatic ring structures with aliphatic side chains.

The three most commonly encountered weathering pathways that affect fugitive petroleum are microbial degradation, evaporation and solubilization.

**Microbial degradation.** There are indigenous microbial populations in most environmental media capable of degrading petroleum given favorable conditions such as availability of oxygen, water, and nutrients. Although almost all of the major chemical classes of petroleum are biodegradable, the normal alkanes are most susceptible to this weathering pathway, and are usually the first compounds to show evidence of degradation following a release.

Because the \( n \)-alkanes dominate the chromatographic features of most petroleum products, this type of weathering is easily identifiable in chromatograms of weathered petroleum. See figure 1, page 31. As petroleum becomes more severely weathered, the more recalcitrant compounds that make up the products begin to degrade. Evidence of severe degradation include diminution of isoprenoids and higher molecular weight PAH compounds and a more pronounced unresolved complex mixture or "hump" in the GC chromatogram.

**Evaporation.** Selective losses of low molecular weight compounds — molecular weight of about 150 a.m.u. and less — due to evaporation can be a significant part of the weathering process.

Obviously, the lighter the spilled product is — gasoline as opposed to crude, for example, the more likely that evaporative losses will constitute a significant portion of the overall weathering. The conditions under which the release occurs obviously determines if evaporation affects the fugitive material.

For example, petroleum products present in the subsurface due to underground storage tank (UST) leaks or releases rarely show evidence of evaporative weathering since they are not exposed to the atmosphere. Chromatographically, evaporative weathering results in a very pronounced diminution of light-end hydrocarbons; that is, those compounds that appear as peaks in the very front-end of the chromatographic trace. A systematic loss of chromatographic signal from about \( \text{C}_{15} \) down to the lowest hydrocarbons measured are good evidence for evaporative weathering.

**Solubilization.** Most hydrocarbons that make up petroleum have low solubility in water, however certain compounds — notably the lower molecular weight aromatics and some low molecular weight aliphatics — have reasonable water solubility. For example, the monoaromatic compounds, principally benzene, ethylbenzene, toluene and the xylenes (BTEX), lesser alkylated benzenes (< \( \text{C}_4 \)), and naphthalene and its \( \text{C}_1 \)-analogues have notable solubilities, such as solubility of benzene at 1780 mg/L to 2-methylnaphthalene - 25 mg/L.

If products containing these compounds contact either surface or groundwater, they can be selectively removed through solubilization, resulting in a weathered product. Light distillate products, especially gasoline, are especially susceptible to this weathering process, and their chromatographic profiles can be severely altered by removal of some of their major chemical constituents that are water-soluble. Notable features of this weathering process are the dramatic relative loss of more water soluble hydrocarbons relative to a less soluble but similar molecular weight hydrocarbon between the fresh and weathered petroleum, such as benzene vs. \( n \)-\( \text{C}_5 \) and naphthalene vs. \( n \)-\( \text{C}_{12} \).

Clearly, petroleum can weather through a variety of processes. Sometimes the weathering is dominated by one process and on other occasions, the petroleum is altered by several or all of the various weathering pathways. In any case, the severity of the weathering
can be classified to help the site investigator understand how the chromatographic features observed for fugitive petroleum relate to the fresh, unaltered material.

- **Unweathered.** The product shows all the chromatographic features of fresh petroleum. Material resembles source product.
- **Slightly weathered.** A sample in which only the most susceptible compounds appear to have been reduced in concentration relative to less susceptible compounds. For example, $n$-alkanes appear slightly reduced relative to similar boiling iso-alkanes or aromatics. The low molecular weight alkanes and aromatics are slightly reduced in concentration relative to fresh product. Major chromatographic features of the product are clearly evident and the product can be easily identified relative to an unweathered standard.
- **Moderately weathered.** A sample in which a substantial portion of the chromatographically resolved compounds, such as $n$-alkanes and lower boiling aromatic compounds, appear to have been lost or dramatically reduced. In the case of a distillate product, this is often apparent by an increase in the unresolved complex mixture and the dominance of previously minor components such as isoprenoids and PAHs in the gas chromatogram. Generally, there is good to limited similarity between the chromatographic signature of a moderately weathered product and the fresh material.

- **Severely weathered.** A sample in which most of the resolved volatile and semi-volatile compounds are absent, no $n$-alkanes are present, and where often the isoprenoids and biomarkers are only remaining measurable resolved compounds in the product’s chromatogram. There are essentially no distinguishing chromatographic features for such weathered products, except for the unresolved complex mixture whose chromatographic position is suggestive of the boiling point range of the original product.

Many differing forces conspire to change the composition and, hence, chromatographic appearance of petroleum once it has entered the environment. Understanding these processes helps frame the interpretation of gas chromatographic analyses of fugitive material, and aids the site investigator in understanding the relative transformation fugitive petroleum has undergone since its release.

Armed with such knowledge, the site investigator can confidently identify and track fugitive petroleum at a study site. If faced with a weathered product that must be distinguished from other petroleum sources of like or different composition, it also allows the investigator to tailor further, more sophisticated chemical analyses and interpret those results in light of the weathering state of the in-place petroleum.

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Write in 333
Put good agricultural principles to use to improve cleanup of soils

By Alfred R. Conklin Jr., Ph.D.

Clean up of contaminated soils using bio and phytoremediation can be accomplished more quickly and completely by applying sound agricultural principles. By adjusting the site environment’s pH, the oxygenation and fertility, maximum advantage is made of biological activity and chemical reactions. In addition, plants which respond vigorously to these optimized

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Natural attenuation is the natural decrease in concentration of pollutants with time. This means the decrease occurs without changing the environment of the site. A sample taken at month 0 will be found to have a higher pollutant level than a sample taken six months later. This will occur without anything being done at the site. The decrease is a result of normal, natural biological activity and abiotic chemical reactions.

This scenario would be similar to one where corn is grown au natural. The corn seed is spread in a field with no preparation, no fertilization and no weeding. In this case, a harvest of 30 kg of grain per hectare (ha) may result. Compare this result to the 300 plus kg per ha which results by applying good agricultural principles; a 10 times increase in productivity. The principles applied to achieve the greater harvest include adjusting the pH, adding fertilizer, working the soil, and picking a variety of corn which responds vigorously to these conditions.

In soil cleanup using bio and phytoremediation, the same principles hold. To obtain an increased rate of cleanup over natural attenuation, an environment conducive to high biological activity must be created. If specific plants or microorganisms are to be used, then the changes in the environment must be geared toward these organisms.

Most often this means adjusting the pH and fertility of the soil. There must be sufficient nitrogen, phosphorous, potassium, and other nutrients available to allow high biological activity. There must be sufficient water to support this increased activity. Equally important is good drainage so that aerobic conditions are maintained.

A word of caution is important regarding drainage and fertilization. Drainage water is often polluted with whatever is polluting the soil. Thus it must be treated before releasing it into the environment. In some cases, this water is used for irrigation of the treatment site. This allows the water to be treated along with and at the same time as the soil. While this is a sound principle, it does present some hazards. Irrigation exposes workers and surrounding areas to the pollutants being removed. Thus, either drip or furrow irrigation is preferred over sprinkler irrigation.

In addition to pollutants in water, there may also be nitrate or phosphate from fertilization. Fertilization requires balancing beneficial and detrimental effects. Nutrients are essential to high biological activity. On the other hand, fertilizer elements can be pollutants. If they are not balanced or are in very high concentrations, they may even inhibit biological activity.

Because of this, a soil analysis is always called for. Usually this will come with a recommendation for pH adjustment and the type of fertilizer required. These recommendations will be a good general starting point for amending soil and will probably suffice unless unusual plants will be used or unusual circumstances exist. See figure 1, page 34.

In all cases, unless legumes are used, nitrogen fertilizers will be needed. Some soils will be low in phosphorus, while others will be low in potassium. Soils are usually not low in both, but sometimes that situation does occur. Other nutrients may also be needed, particularly micronutrients. When working with industrial pollution, soil testing for micronutrients is particularly important. Excess micronutrients are toxic to plants. For this reason, the occurrence or application of micronutrients is an important consideration.

The proper application of plant nutrients will provide an environment conducive to vigorous biological activity. The next step is to choose organisms which are also very vigorous. All plants will grow more vigorously under certain conditions but some will respond more than others.

Consider the example of the corn. Under exactly the same soil, water, fertility, sunlight, day length, and

Continues on page 34 →

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Alfred R. Conklin Jr., Ph.D., is a professor in the agriculture department of Wilmington College, Wilmington, Ohio.

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Write in 110
<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Nitrogen (N)</th>
<th>Phosphorus (P)</th>
<th>Potassium (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5-7.0</td>
<td>36 kg/ha</td>
<td>7 kg/ha</td>
<td>36 to 55 kg/ha*</td>
</tr>
<tr>
<td>Less than pH 6.5</td>
<td>Can be ammonia or nitrate.</td>
<td>Usually as super phosphate.</td>
<td>Usually as potassium chloride also called murate of potash.</td>
</tr>
<tr>
<td>lime: Higher than 7.0 acidity.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Recommended potassium levels are related to a soil’s CEC so local interpretation of soil analysis is extremely important.

Figure 1: Common desirable levels of nutrients in soil

Academix, from page 33

temperature conditions, some corn plants will produce more than others. Some will grow taller; some will yield more; and some will grow faster. The same is true for plants used for phytoremediation. The faster the plants grow, the more nutrients, water and air they will need. At the same time, the faster they grow the more pollutants they will degrade. One may consider using a slow growing tree such as an oak or evergreen, which grow a few centimeters a year, at a remediation site. But when comparing these slow growers to a hybrid poplar, which grows several meters per year, the poplar comes out ahead because with its higher activity and more intense growth pattern, it is more effective in degrading pollutants.

In addition to plants, there are also a whole host of microorganisms in the soil. Soil microorganisms will also respond to an idealized environment. Optimum soil water, air, and fertility are conducive to high microbial activity and are generally the same as those optimum for plant growth. With these optimum levels, high microbial activity results in rapid breakdown of pollutants.

While there has been much success in transplanting plants from one local to another, there has not been equal success with microorganisms. There are microorganisms which are highly effective in degrading pollutants. These microorganisms can be applied to soil and they will degrade the pollutant. However, they will not live long in soil. Because of the high microbial population in soil, these organisms cannot compete. Also, they are subject to predation by numerous other organisms.

There are several ways in which this limitation may be overcome. Soil can be reinculcated on a regular basis. This can be an effective means of degrading soil pollutants. A microorganism can also be selected which can degrade the pollutant and persist in soil. Or, an organism which will persist in the rhizosphere of a particular plant can be paired with that plant in the cleanup effort.

It is important to optimize the soil when using bio or phytoremediation to remediate a site. This involves optimizing the soil conditions and using plants and microorganisms which have high biological activity. Optimization will encourage the fastest and most complete cleanup.

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Write in 114

Soil & Groundwater Cleanup August/September 1998 35
The impact berm at a small arms range in a marine environment shows evidence of erosion from bullets. Investigators collect soil samples at the range site.

Assessment is key in targeting cleanups at skeet, small arms ranges

By Timothy J. Peck, Daniel A. Hinckley, Ph.D. and Todd Ward

Regulatory action on shooting ranges, including skeet and trap and small arms ranges, has varied in the past across the United States depending on the site setting, decisions made by local regulators, and whether the range is active or closed. Considering recent regulatory action and decisions, state and federal regulators may advance environmental assessment and remediation of shooting range locations to a greater degree than in the past.

There is ongoing litigation in the U.S. Federal District Court in New York concerning skeet and trap ranges where Clean Water Act, RCRA and CERCLA regulatory issues are being considered. The dispersal of lead bullets and shot, and clay targets into waters of the United States may eventually be defined as pollutant discharge according to the Clean Water Act and, therefore, the range operations may require a National Pollutant Discharge Elimination System (NPDES) permit.

While the U.S. EPA currently does not consider weapon and target discharge as waste disposal, the EPA has classified some defunct ranges as RCRA Solid Waste Management Units subject to corrective action. Under RCRA, federal courts may order remedial actions where there is imminent and substantial endangerment to human health or the environment, and citizens may bring lawsuits requesting relief.

In accordance with RCRA Section 3004, the Munitions Rule defines regulations to identify when conventional and chemical military munitions, including small arms ammunition, become hazardous waste subject to RCRA procedures for the safe storage and transportation of these hazardous wastes and procedures concerning emergency response. Used munitions are defined as solid waste when transported off-range for treatment or disposal, or recovered, collected and disposed on or off range such as being buried or placed in a landfill, but not part of normal on-range clearance or maintenance operations. The proposed Department of Defense Range Rule will address munitions at closed or transferred ranges.

Continues on page 38 →
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### Figure 1: Summary of metal analytical results in sampled media at freshwater wetland skeet and trap range

**Assessment, from page 36**

The thousands of military and civilian shooting ranges in the United States potentially affect a variety of environment types, including terrestrial, wetland, estuarine, marine, and freshwater streams and rivers. The chemical fate and transport of heavy metals at ranges is dependent upon the physical and chemical properties at the site.

Each environment will attract different sensitive receptors, which may be at risk to metal exposure. Because of the potential for increased regulation of current and formerly used shooting ranges and the varied environmental conditions, methods of assessment must be designed to accurately and cost-effectively assess impacts to correctly evaluate the environmental liability.

**Sampling design planning**

The planning of a site assessment for skeet and trap sites and rifle ranges should involve not only the project manager, but also the field characterization manager, risk manager, human health and ecological risk assessors, and environmental chemists to assure that the data necessary to meet the objectives of the site assessment are obtained.

The risk manager will play an important role in decisions concerning site management including risk assessment results, political pressures, and financial limitations. Site human health and ecological risk assessments are frequently required by regulators. Both human health and ecological risk assessors assess the variety of exposure pathways to receptor organisms.

For example, ecological risk assessment needs to examine the type of environment where the shot is landing. Many skeet and trap sites are located where the shooting field is directly in a wetland, necessitating assessing the potential for waterfowl exposure to lead shot. Alternatively, the shooting field may be a terrestrial system, resulting in different potential receptors such as deer, rodents or soil invertebrates. Environmental chemists may need to examine the fate and transport of lead shot in the environment and so will require data on field chemistry.

**Site assessment methods**

Site characterization should consider the following objectives: the accurate assessment of the extent, concentration, and speciation of metal contamination; measurement of lead shot density to measure probability of waterfowl ingestion; soil particle gradation; soil or water chemistry, such as water hardness, pH, dissolved oxygen, Eh, salinity, total organic carbon, cation-exchange capacity, and bulk density; assess the presence of co-contaminants; and identify potential sensitive receptors.

In evaluating the potential for metal mobility in the subsurface, the Synthetic Precipitation Leaching Procedure, or EPA Method 1312, is
more appropriate to assess potential for leaching under acid rain conditions rather than the Toxicity Characteristic Leaching Procedure (TCLP), which is designed for landfill conditions. Simultaneously extracted metals/acid volatile sulfide (SEM/AVS) can be used in sediment benthos risk characterization. It is known that divalent metals precipitate with sulfide in anoxic sediments. Precipitated metal sulfide is insoluble and is not bioavailable. Also, considering most regulatory water quality standards are based on dissolved metal concentrations, total and dissolved metals in water should be measured.

Gun shot and small arms bullets are primarily composed of lead as well as traces of antimony, arsenic and copper. Site assessments predominantly target lead, because lead is the most critical metal considering its toxicity, mobility and availability.

**Case studies illustrate variations**

EA Engineering, Science, and Technology Inc., Sparks, Md., has conducted environmental investigations at many skeet and trap and small arms ranges in the United States. In these investigations, sampling plans were developed to obtain the information required for groundwater and hydrologic modelers, human and ecological risk assessors, and the risk manager. Three ranges with varying site settings illustrate the variations in sampling design to meet project objectives.

**Skeet and trap range in freshwater wetland**

This study of a range which operated for 30 years aimed to examine the potential for site contamination associated with a skeet and trap range and to provide a preliminary assessment of potential human health and ecological risks. The study included assessing the nature and extent of lead, arsenic, and antimony in soil, sediment, groundwater, surface water and biota; assessing the extent of lead shot in soil and sediment; examining the potential for contaminant transport to surface water bodies; and characterizing and assessing potential risks to ecological communities at the site.

The range is located in the northeastern United States. The geology consists of crystalline bedrock overlain by unconsolidated glacial deposits and recent alluvium. Water table depth ranges from 0.5 to 3 m. The average hydraulic conductivity of the unconfined aquifer was 6.7E-4 m/sec. Wetlands are significant and characterized by an open stream flowing through a wet meadow containing floating, submerged, and emergent plants, bounded on higher ground by shrubs and trees.

Selection of soil sample locations was initiated by establishing quadrants in the potential 180° impact area. Radial quadrants were delineated by marking two 40° angles on each side of the semi-circular area where low shot density is expected and dividing in half the remaining central radial quadrant where most shot would fall. These four quadrants were further divided with transecting concentric semi-circles, where most shot was expected to fall between 90 and 200 m from the shooting positions. Sample locations were allotted to each quadrant, while quadrants with greater probability of lead deposition were assigned more samples and samples that included SEM/AVS analyses. Soil samples selected for total metal analysis were not sieved to remove shot. A separate set of soil samples were wet sieved to measure weight of shot per unit volume and per unit mass.

Surface water and sediment samples were collected in the main stream channel and two tributaries. Most sampling stations were located where stream flow characteristics changed or before and after tributary input. Up- and downgradient samples were collected more than 150 m off the range.

The highest metal concentrations in soil occur within 90 to 200 m of the shooting positions. See figure 1, page 38. Lead concentrations in sieved soil samples were up to 2,690 mg/kg. Surface water and groundwater results did not indicate significant migration of lead outside of the range area due to high soil-water partition coefficient (Kd) for lead, resulting in most lead being adsorbed to solids.

Based on the results of lead shot quantification across the range in soil up to 15 cm deep, the total mass of lead shot was calculated to be 77 metric tons. SEM/AVS results of five stream sediment samples are summarized in figure 2, page 42. The SEM/AVS ratios greater than 1.0, predominantly due to extracted lead concentrations that ranged from 26.3 to 48,300 µg/L, indicated that sediment in the deposition zone may present risks to benthic organisms due to exposure to lead.

Both flora and fauna analyses showed elevated levels of antimony, arsenic and lead. There were significant human health risks related to blood lead levels from contaminant transfers in the food chain and significant ecological risks due to contaminated soil and sediment. Remedial alternatives were evaluated; however, to avoid destruction of wetlands, controlling human access to the site was considered to be the most beneficial for the environment.

**Skeet and trap range in saltwater wetland**

A skeet and trap range located within a U.S. military facility on the Atlantic Coastal Plain operated for about 30 years. The objectives of this study were to assess the concentration and extent of lead in surface water and sediment across the range for evaluation of compliance with federal and state

Continues on page 42 ➔
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Figure 2: Summary of AVS and SEM results for five sediment samples

Assessment, from page 39

environmental regulations including the Clean Water Act. The measured lead levels in sediment and surface water were compared to federal and state regulatory standards and guidance criteria to evaluate regulatory compliance of lead concentrations in the environment and potential risks to human health and the environment. The range was located predominantly within a tidal saltmarsh area, which is periodically inundated during high tide, and over open surface water. Sediment was composed of silt and fine sand. Due to the restricted number of samples and sample spacing required in the project scope, the samples could not be spaced across the entire, potential impact area; however, most samples were located within the center 90-230 m impact area. Soil and sediment samples were collected up to 15 cm deep and were sieved with a 1.65 mm sieve to remove shot fragments. However, during the study, lead shot was rarely observed in the apparent corrosive saline environment with 6-9 pH, -200-+300 mV Eh, and about 20 ppt salinity.

Lead concentrations in sieved and non-sieved sediment and soil samples were similar, due to the prevailing absence of large lead particles. The highest lead concentration occurred in the 90-200 m area. Ranges of lead

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concentrations in non-sieved sediment and dissolved surface water were 5 to 37,100 mg/kg and 15 to 143 μg/L, respectively.

Lead concentrations in sediment in the offshore area were significantly lower, up to 142 mg/kg, which is perhaps due to sinking of shot into the bottom sediment or shot being buried by sedimentation.

Considering that lead shot was not observed during sampling, the distribution of total lead in sediment suggests that the shot has been weathered and remains within the marsh sediment, but also may have been mobilized by tidal surges across the marsh where elevated lead levels occurred beyond the expected impact area. Background lead level in the area was less than 10 mg/kg.

**Small arms & rifle ranges in marine environment**

Adjacent small arms and rifle ranges located within a U.S. military facility on the Atlantic Coastal Plain were operated for about 30 years. The objectives of the study were similar to the military skeet range described previously. In general, the ranges were constructed of impact and side berms, a series of elevated, wooden baffles to capture stray bullets and movable targets set at varying distances between the baffles and impact berms. Pistols and M-16 rifles were used at the small arms range.

Continues on page 44 →

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Due to erosion by bullet impact, soil on the impact berms collapsed down the face. Occasionally, this soil was bulldozed back to the face of the berm, which created a layered structure to the berm faces. A partially forested, tidal saltwater marsh was located beyond the ranges, which is periodically inundated during high tide. Surface water drainage from each of the range floors was directed to conduits located on the downrange end of the side berm, which discharged into the tidal marsh. Soil was composed of silty clay to silty fine sand. Sediment within the marsh was composed of silt and fine sand.

Within the ranges, surface soil samples were collected on a 20 m grid across the range floor and along three levels on the impact berm faces including horizontal borings in the faces up to 2.3 m deep. The boring depths were designed to extend to the expected bullet penetration depth considering the aggraded soil layers on the berm. Surface soil and sediment samples were collected up to 15 cm deep and were sieved with a 1.65 mm sieve to remove lead fragments.

The range of lead concentrations in sieved samples within certain locations inside the ranges and in the marsh beyond the ranges are listed in figure 3, page 43. Background lead level is about 10 mg/kg. Within the ranges, the concentrated lead in the impact berms was obvious, while lead concentrations across the range floors were also elevated significantly. Lead concentrations were significantly elevated at the 2.3 m depths of the horizontal borings in the main impact area with up to 46,600 mg/kg at the rifle range and up to 10,100 mg/kg at the small arms range, which indicated that lead concentrations were elevated deeper into the berms.

Lead fragments were commonly observed in the impact berm, but rarely in the range floors. Though the mean and upper limit of lead concentrations were generally higher for the non-sieved soil samples, it appeared that sieving of soil samples did not separate a significant amount of lead. Lead levels that exceeded regulatory screening criteria were more frequent for the sieved samples than for the non-sieved samples. Commonly, sieved sample results had higher concentrations perhaps due to removal of lead-free particles from the sample. Lead in soil at the ranges was likely present as fine particles, smears, and weathered products. Weathered lead commonly was observed in the berms as white or yellow stained soil. Soil at the ranges had a pH of 5 to 8 and Eh of 100 to 400 mV. The microparticulate forms of lead in impact berms are significant in consideration of lead mobility and management options at shooting ranges.

In sediment samples collected in the wetlands behind the ranges, lead fragments were rarely observed in the apparent corrosive saline environment with 6 to 9 pH, -200 to +300 mV Eh, and about 20 ppt salinity. Lead concentrations in non-sieved samples were significantly above the background level of 10 mg/kg over large areas beyond the range berms, ranging from 5 to 29,700 mg/kg. Sieved sample lead concentrations were up to 486 mg/kg.

Based on the detected concentrations, bullets that traveled over the impact berms tended to fall in two areas, about 30 to 90 m and 200 to 450 m beyond the berm. These patterns were controlled by interception by tree vegetation to some degree. Lead fragments were not observed in the wooded area. The distribution of lead concentrations appeared to indicate mobilization of lead across the tidal saltmarsh and along tidal stream channels by tidal flows. The depressed lead concentrations in the wooded area of slightly elevated land beyond the berms may have been due to the lack of lead mobilization, which otherwise appears to be prevalent in the marsh.

A multi-keyed approach

Regulatory action addressing shooting ranges is expected to be a higher priority as the impacts of ranges on the environment are more closely scrutinized. The accurate environmental assessment of shooting ranges must include an understanding of the environmental setting, chemical fate and transport of metals, and the sensitive receptors that may be at risk.

To address these issues, an effective project team must be assembled. Site characterization methods should include assessment of metal contamination, physical and chemical conditions, identification of sensitive receptors, leaching potential, quantification of shot density and SEM/AVS to provide a realistic measure of metal bioavailability.
Within skeet and trap ranges, the highest lead and shot concentrations consistently occurred in the 90 to 200 m range within a 100° arc from the shooting positions. Under certain chemical and physical conditions, such as marine areas affected by tidal surges, degradation of lead and significant transport of lead outside of the impact zone may occur. In a marine environment, sieving was shown to not significantly separate lead from sediment and soil samples due to the degradation of lead fragments to microparticulate forms.

Within small arms and rifle ranges, bullets concentrate in the impact berm, but some bullets will collect across the range floor and in side berms, and some will ricochet over the berm and fall possibly several hundred meters beyond the berm. Depending on maintenance operations of the impact berm, bullet penetration may occur several meters into the berm. Lead particulate from gun emissions may also accumulate near the shooting positions.

Northern Lake Service Inc. has a website that features information on NLS and analytical chemistry services for remediation contractors and consultants in Region V and elsewhere. A new hard-copy brochure will be offered at the site soon. Visit this site at: www.northernlakeservice.com.

The Environmental Technology Center, on Otis ANG Base in Massachusetts, has a website featuring its work at finding and demonstrating new groundwater cleanup technologies for the base. The site is located on the web at: www.envirotechcenter.org.

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