Military Sites & Brownfields

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You may have noticed we've shortened our name a bit on the cover. Our attempt to make the name a little less of a mouthful, while still saying to the industry who we are and what we do. We've done a little updating throughout this issue. Let's just call it our new look for the new millenium.

Speaking of the new millenium, on page 41 is our preliminary editorial calendar for next year. We are seeking articles from industry experts and participants, primarily dealing with site specific information. Feel free to call or e-mail if you have an article concept for any of the issues on the 2000 calendar.

Terry W Combs
Managing Editor/Publisher
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Soil & Groundwater August/September 1999
Thule Air Force Base, Greenland

Biological Soil Treatment Above the Arctic Circle

The Thule, Greenland site 700 miles above the Arctic Circle.

By Brian Clark

The first successful cold weather biological soil treatment was completed at Thule Air Force Base, Thule, Greenland. Located 700 miles north of the Arctic Circle, Thule Air Base (TAB) is the northernmost, permanently manned installation operated by the U.S. Department of Defense.

The harsh environment required bioremediation methods that were extremely robust and fast acting. The limited window to complete the project between the spring thaw and winter freeze allowed only a three month treatment period with a relatively low ambient temperature.

Conventional bioremediation techniques were considered too slow to be an effective option. Proprietary multi-enzyme complexes in combination with a highly specialized TPH bacterial consortium were used to achieve extremely rapid rates of reduction.

The specialized enzyme was specifically developed to act on petroleum hydrocarbons. These enzymes are complex three-dimensional proteins that are extracted directly from living TPH-degrading bacterial cultures. The addition of enzymes significantly increases the rate of contaminant degradation, even in overly wet and cold conditions. Conditions that are not normally conducive to conventional bioremediation techniques. Enzymes catalyze the degradation of petroleum compounds even in the absence of bacteria. Because enzymes are not living cells like bacteria, they are much less susceptible to environmental factors, including temperature, moisture and pH conditions.

Location and Contaminant

In the winter of 1997, TAB experienced a significant release of JP-8 fuel oil from a leaking, snow-covered valve on an above ground pipeline used to transfer fuel from the fuel storage area to other areas of the base. The leaking valve was located on a hillside approximately 500 feet from a waterway that flows roughly one mile to North Star Bay during the summer months.

An estimated 35,000 gallons of JP-8 was released from the pipeline, and subsequent soil excavation revealed additional contamination from earlier undocumented releases. The combined estimated release volume was 110,000 gallons. After snow was cleared from the release

Work in process at Thule site.

_Brian Clark, P.E., is executive vice president with Enzyme Technologies Inc., Portland, Ore._

8 August/September 1999 Soil & Groundwater
route, fuel was observed seeping from the hillside and pooling in the riverbed.

The treaty agreement between the United States, Denmark and Greenland that governs the operation of TAB prohibits the introduction of substance into North Star Bay that could be harmful to the sea life. The treaty also prohibits the introduction of any substance that affects the taste of fish or mammals that are harvested for food by the local Inuit population.

To prevent fuel from entering the river and flowing into the bay during spring thaw, the Air Force decided to excavate the contaminated soil from the hillside and riverbed. The riverbed and portion of hillside affecting channel flow were reconstructed to their natural contours following excavation to prevent excessive scouring during spring thaw. At completion of the excavation activities, approximately 16,000 cubic yards (cy) of contaminated soil had been removed and stockpiled.

The logistical obstacles of getting equipment into and out of Northern Greenland made all equipment-intensive remediation methods, such as thermal treatment, cost prohibitive. A biological solution was considered the most feasible; however, the short Arctic summer limits the available treatment period to roughly three months. In addition, the average ambient daytime temperature during the summer months is 40° to 50° Fahrenheit. TAB is subject to strong winds that make maintaining soil moisture difficult. In order to be successful, any biological treatment would have to be extremely fast acting.

The Bioremediation System

In practice, a bioremediation system requires an enzyme that can degrade the target compound (target-specific), having the enzyme generator (bacteria) present in the contaminated area, and then inducing the bacteria to produce the enzyme. The inducement is an energy and carbon source (usually the target contaminant). For the micro-organism to obtain energy from the

Continues on page 10 →

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Figure 1: Multi-Enzyme Complex Degradation Pathway

Multi-Enzyme Complexes

ALKANE (OIL) → ALOCHOL → ALDEHYDE

O₂

NEW CELLS CO₂ H₂O → FATTY ACIDS (easy carbons)

Bacteria

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Soil & Groundwater August/September 1999
contaminant, it must pass through the cell wall (via diffusion) so that the cell's electron transport system can be used for energy storage. In the absence of added enzymes, these diffusion steps occur very slowly, which correlates to slow degradation of the contaminants. Adding the highly specific multi-enzyme complexes bypasses this slow process and significantly enhances degradation rates. (Figure 1)

Bacteria gain energy through oxidation-reduction (redox) reactions. Oxidation is the removal of electrons from a molecule, and reduction is the addition of electrons. Oxidation cannot occur without reduction (hence the name of the reaction), and the electron flow generated in the redox reaction is called electron transport. Each step in the oxidation of an organic compound requires the removal of two electrons and the correlated loss of two protons. This is equivalent to the removal of two hydrogen atoms and is therefore called dehydrogenation. Reduction requires the addition of two electrons and two protons and is called hydrogenation.

Each time that an organic compound is oxidized (through hydrogenation), the compound is transformed to a new organic compound. For an alkane (as is present in diesel fuel), this process involves oxidation from the parent molecule (the alkane) to an alcohol, then an aldehyde, until it reaches a fatty acid. An electron acceptor must be present during each oxidation reaction to accept the released electrons, and is thereby reduced. For aerobic degradation, the electron acceptor is molecular oxygen, and the metabolism process is called respiration.

The specialized multi-enzyme complexes catalyze these redox reactions and result in the breakdown of long chain aliphatic hydrocarbons (diesel and oil) to simple fatty acids. Without these enzymes, chemical degradation may take years to occur because the activation energy necessary to trigger the redox reaction is too great. The enzymes accelerate the redox reactions by lowering the required activation energy, resulting in rapid conversion of the complex petroleum hydrocarbons to simply fatty acids. The resulting fatty acids are easily degraded by the bacteria, resulting in complete degradation of the contaminant to carbon dioxide and water (mineralization).

**The Pilot Test**

A treatability study was planned on 1,000 cy of soil using the enzyme enhanced bioremediation process. A landfarm was constructed on TAB, and the soil was placed to a depth of 12 inches. An additional 100 cy of soil from a 1998 release was also incorporated in the landfarm. The 1,000 cy of soil contained an average concentration of 5,000 ppm gasoline-range petroleum hydrocarbons and 5,000 ppm diesel-range petroleum hydrocarbons for an aggregate concentration of 10,000 ppm. The additional 100 cy of soil were saturated with free product, and contained an average concentration of 37,000 ppm diesel-range petroleum hydrocarbons.

A small tractor was available on-site for till operations, so a matched tiller was shipped to the site. Multi-enzyme complexes and TPH degrading bacteria were also shipped to the site, along with a nutrient mixture specially prepared for the site. Following construction of the landfarm, the soil was inoculated with the multi-enzyme complexes followed by the bacterial consortium and nutrients. Monitoring and re-application were performed every 30 days during the 90 day treatment period to ensure optimum degradation over the short treatment time frame. The soil was tilled twice weekly to provide oxygenation for the enzymes and bacteria, and moisture was maintained by spraying the soil with the water cannons from a base fire truck.

Soil samples were collected every 30 days and shipped back to an AFCEE approved laboratory in the U.S. for analysis of gasoline (GRC) and diesel range organics (DRO) by EPA Method 8015M.

Figures 2 and 3 illustrate the effectiveness of the enzyme enhanced bioremediation process from the 1,000 cy soil volume. Figure 1 shows the baseline GRO samples ranging from 2,880 mg/kg (ppm) to 5,450 ppm. These concentrations were all reduced to less than 150 ppm in the first 30 days of treatment, and were all nearly non-detectable within 60 days. Figure 2 shows the baseline DRO samples ranging from 563 ppm to 4,770 ppm. After a brief acclimation period in the first 30 days, these samples showed a rapid decline in the 60 and 90
day sampling events. At the end of the 90 day treatment period, the DRO concentrations were reduced to between non-detect and 219 ppm.

Figure 4 illustrates the treatment results for the 100 cy from the 1998 release. The soil was very heavily contaminated with baseline concentrations of 5,450 ppm GRO and 37,300 ppm DRO. The GRO fraction was reduced to 134 ppm in the first 30 days and was non-detectable after 60 days of treatment. The DRO fraction showed a significant decline over the entire treatment period, with a final result of 2,600 ppm, a 93% total reduction.

**Comparative Costs**

The overall cost to perform the remediation process was estimated to be $105 per cubic yard, inclusive of landfarm construction, soil inoculation, tilling and sampling. Based on economies of scale associated with treating larger soil volumes, the cost of treatment for additional soils is expected to be 25% lower than the pilot test treatment cost, resulting in an overall cost of $75-$80 per cubic yard.

In contrast, thermal treatment of the soil was estimated at $250-$275 per cy, primarily given the logistical difficulties of mobilizing the necessary equipment to the site. Treatment by conventional bioremediation techniques was estimated to cost $175-$200 per cy, with a three-five year required treatment period. Equivalent treatment costs for ex situ soil treatment using enzyme enhanced bioremediation in the contiguous United States are estimated to be $25-$35 per cubic yard, inclusive of landfarm construction, maintenance and sampling costs.

The first successful cold weather biological soil treatment was completed against great odds above the Arctic Circle. Because of the extremely short window of time for remediation in arctic regions, the addition of enzyme solutions to facilitate molecular breakdown of the hydrocarbon chain establishes this technology as a viable, cost effective cleanup solution for these sites. Based on the success of the pilot test, a contract for full scale soil treatment has been awarded at Thule Air Force Base.
Ammonium picrate is a yellow crystalline solid that is used in explosives, fireworks and as a rocket propellant. Several different names are used to describe ammonium picrate such as Yellow D and Explosive D. This is not a common explosive and the treatment of soil contaminated with it is not well established.

Hawthorne Army Depot (HAWD) in Hawthorne, Nev., was opened in 1928. HAWD has been actively assembling, storing, testing, shipping and decommissioning explosive ordinance ever since.

Approximately 70,000 cubic yards of soil are contaminated with explosives. About 10,000 cubic yards of which is contaminated with ammonium picrate. Concentrations varied from laboratory detection limits (2.5mg/kg via EPA Method 8330M) to an 18 inch layer of pure product. Areas with the most contamination were unlined washout basins that were attached to decommissioning activities.

Information on ammonium picrate is limited and information on treatment technologies is scarce. It was determined that composting ammonium picrate had not been tried before. Therefore, the decision was made to first conduct a bench scale test of the process. If this test degraded the ammonium picrate, then a pilot scale test would be made with 300 cubic yards of ammonium picrate contaminated soil.

**Bench Scale**

The bench scale test was conducted to answer two questions. Would composting degrade ammonium picrate, and would any harmful by-products be generated? The test consisted of six 1.5 cubic foot styrofoam containers; two each for both aerobic and anaerobic conditions; plus two others under aerobic conditions with a different carbon source. The soil used in all of the composting work at HAWD is a well graded sand. The compost mixture was, by volume, 30% contaminated soil, 20% wood chips, 20% potato waste, 15% steer manure and 15% hay. The recipe for the two additional aerobic containers had the potatoes substituted with molasses for the carbon source. The amendments and contaminated soil were mixed by hand and placed in the containers.

Samples were taken of the initial soil concentrations, the blended soil concentrations and the initial compost mix concentrations. One compost sample was collected from each container, every two days. At the same time, temperature and moisture measurements were also recorded. Moisture in the mix was maintained between 50-55% of the water holding content. Moisture was measured by weighing, oven drying and reweighing samples. Anaerobic containers had the mix turred every four days. All aerobic containers had the compost mixture turred each day and moisture added if necessary. All samples were analyzed via EPA Methods 8330 and 8330M.

There is no regulatory criteria established for ammonium picrate. However, a proposed cleanup goal of 7 mg/kg was adopted after discussions with the State of Nevada.

**Bench Scale Results**

Initial soil testing indicated that the ammonium picrate concentrations were near 30,000 mg/kg. This initial concentration was reduced by blending with clean soil until the contamination concentration was near 10,000 mg/kg. Clean soil for blending was taken from a local borrow area. This blending was done to make the material safer to handle and to reduce the concentration to a range that was not as toxic to the bacteria. After the compost mix was assembled, the ammonium picrate concentration was tested to be about 3,000 mg/kg. Initial concentrations varied between 2,700 mg/kg to 3,500 mg/kg. Test results indicated that both the aerobic and anaerobic systems degraded the ammonium picrate to below the detection level of 2.5 mg/kg.

As expected, the aerobic system degraded the ammonium picrate faster than the anaerobic system. The aerobic cells reached and stayed at non-detect (<2.5ppm) in 10 days. The anaerobic cells reached the same state in 14 days. The set of cells which had the substitution of molasses for potatoes did not work.
The bench test was run twice. The first test did not seem to be working. Temperatures in the compost piles did not increase as was expected. In the second test, temperatures rose into acceptable range (>45°C) quickly. The difference between the two tests was the use of cedar wood chips, intended for pet cages, that were used first. Common pine wood chips were used in the second test. The problem was the apparent natural toxic effect on bacteria from the cedar chips. The subdued bacteria resulted in a slowed reaction in the compost piles.

The failure of the molasses substituted for potatoes was most probably caused by the need for a larger volume of molasses than anticipated. Without an adequate carbon source, the bacteria did not have had a chance to multiply.

**Ammunition Boxes Used in Pilot Scale Test**

The pilot scale test was scheduled to compost 2,500 cubic yards of TNT contaminated soil. The test was modified to include an additional 300 cubic yards of ammonium picrate contaminated soil in separate windrows.

Operating the pilot test on this scale provided the opportunity to assess the composting method while evaluating the full scale production equipment and the economic availability of amendments. While the TNT contaminated soil was run with four different amendment recipes, the ammonium picrate soil recipe was the same as was used in the bench scale test.

One of the questions that the pilot scale test had to answer was: Can we economically assemble enough amendments when we need them? Hay, fresh manure and potato waste were readily available from local sources. Later when the potato plant at Winnemuca, Nev., could not keep up with the demand, whole potatoes were delivered from Malin, Ore., and Nampa, Idaho. Wood chips were a difficult item to obtain, as trees are not plentiful in the Hawthorne section of Nevada. Some tree trimmings were on hand from base activities, but not nearly enough for the project needs.

However, the base had accumulated a small mountain of old oak and yellow pine ammunition boxes that were destined for a landfill. The solution was to use a heavy duty wood chipper to reduce the wood boxes to wood chips. Although the nails and hinges on the boxes did not cause a problem with the chipping process or the composting action, they did cause a physical hazard with the composting equipment and personnel.

The piles of amendments and contaminated soil were assembled near the selected composting site. Soil samples were taken of the initial soil, the mixed soil and the initial compost mix. As before, the initial soil concentrations were in excess of 30,000 mg/kg of ammonium picrate.

Clean soil was blended into the contaminated soil to reduce the contaminant concentration to below 10,000 ppm. Again, blending was done to allow safe handling of the explosive and reduce the toxic shock to the bacteria.

The windrows were constructed, watered and turned three times with the compost turner before the initial compost sample was taken. This was done to get a more homogeneous blend of the windrows as there was no premixing of the soil and amendments.

The windrows were triangular shaped, about six feet high, 12 feet wide at the base and about 320 feet long. As time went by, the windrow height was reduced to about three feet high by the composting action. Each morning the water truck would apply about 1,000 gallons of water on each windrow, and the compost turner then would turn each windrow. Temperature and moisture readings were taken twice.

Continues on page 14 →
Ammonium, from page 13 a day, and additional water was added if the windrows appeared to require more moisture.

An impervious pad was not constructed beneath the windrow, nor was there any structure covering the windrows to control the climate. The windrows were constructed perpendicular to the prevailing winds, and a larger clean soil windrow was placed at each end of the windrow field as a windbreak.

Initial compost mixtures averaged about 3,500 mg/kg of ammonium picrate. The windrows quickly developed their operating temperatures to a range between 50-60ºC. After 16 days, samples from the windrows indicated that the ammonium picrate levels had dropped to below the detection limit of 2.5 mg/kg. Samples taken six inches beneath the windrows were sent to a laboratory, and neither ammonium picrate, or any decomposition compound was detected; indicating no migration of the explosives from the compost piles.

Whole potatoes did the job as well as potato waste. Using the compost turner to break up the whole potatoes saved time and money. The greatest disadvantage with using whole potatoes was the cost being higher as compared with potato waste.

The odor of the compost system was not a problem, but in a more populated area this could be an issue. Odor was the strongest during windrow construction when there were piles of potato waste and fresh manure. Even then, beyond 200 yards the odor from the area was difficult to detect. As the composting action went on, the odor from the piles was less like manure and more like a highly organic soil.

Finally, the expectation was to replace the teeth of the compost turner about every 8-10 days. This did not impact the down time for the compost turner as all windrows could be turned in less than four hours. These equipment repairs did impact the project costs for the increased materials and labor.

Conclusion

It was the intent of these tests to answer two questions. Can composting biodegrade ammonium picrate, and are there any compounds produced in the process that are of environmental concern?

First, ammonium picrate is successfully biodegraded by the composting action. Reduction of ammonium picrate from 3,500 mg/kg to non-detect in 16 days supports this claim. Analysis of samples collected in the compost piles and under the bottom of the compost piles did not indicate any compounds that were of any environmental concern.

This study has shown that windrow composting can clean up soil contaminated with ammonium picrate. The remediation costs would be expected to be in the range of $150-$200 per cubic yard of contaminated soil.
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Brownfield Redevelopment
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By Stephen A. Serfass, Esq.

The landscape of urban America is littered with abandoned industrial sites, unused rail yards, closed military bases and former gas stations. And other similar sites, which despite their current appearance as eyesores, present significant business opportunities. These “brownfields” are not only wasted resources, they significantly erode the tax base and contribute to urban blight and economic decline in historically industrial urban centers.

Brownfields are abandoned, contaminated industrial sites that, although tarnished by pollution, are not listed among the country’s most heavily polluted lands. In most cases, the severity of the present contamination does not warrant immediate action from the federal government, but does pose risks significant enough to dissuade developers from investing in the contaminated land. Thus, while brownfields are not subject to cost associated with Superfund or National Priorities List status, in an undeveloped state, brownfields do adversely impact local economies and raise substantial pollution issues in the community.

Stephen A. Serfass is a claims counsel with ECS Claims Administrators Inc., Exton, Penn.

Government Incentives for Redevelopment
Recognizing the advantages of locating new industrial or commercial facilities that store or handle hazardous substances at locations that have existing environmental contamination, the EPA has recently loosened its grip with respect to brownfield redevelopment projects. In doing so, the EPA implemented three methods of providing incentive for redevelopment: (1) reduction of cleanup standards; (2) the provision of grant money for redevelopment projects; and (3) the removal of many sites from Comprehensive Environmental Resource Recovery Act (CERCLA) registry.

The EPA’s motivation for establishing these incentives include expediting the cleanup process, promoting economic redevelopment and promoting equity in cleanup enforcement. The EPA and lawmakers now seek to balance the scales between protecting human health and the environment and encouraging property development and industry.

The EPA has lowered cleanup standards by adopting a “use based” cleanup approach. This approach, using a risk based corrective actions program, allows for a shift in the cleanup target level based on the actual site specific risk of exposure, not on an assumption that everyone will be exposed to the contamination. Thus, a party interested in redeveloping a brownfield is only required to clean the property to a point where the toxicity is at a level consistent with and acceptable for the property future intended use.

Additionally, the EPA has moved the point of compliance from the point of contamination to the property boundary, resulting in significantly reduced cleanup costs. In addition to loosening the reigns of cleanup, the EPA also provided incentives for redevelopment in the form of grants of up to $200,000 to each of 78 pilot projects in it’s “Brownfields Actions Agenda”. Grant money is typically used to estimate costs of cleanup and develop a suitable work plan for redevelopment.

Finally, the EPA also removed approximately 27,000 sites from CERCLA’s registry of targets for enforcement action. By doing so, the EPA removed at least part of the stigma associated with these sites, and reduced the likelihood of a redevelopment effort being weighed down or stopped by potential CERCLA liability.

Recognizing the potential positive impact to urban areas, state
governments have also rallied behind the brownfield redevelopment movement. A number of states have moved away from strict liability schemes and enforcement actions under CERCLA, toward a more incentive driven approach designed to bring businesses back to increasingly desolate urban areas. Approximately 30 states have instituted some means of protecting potential participants by capping liability and thus allowing them to make more accurate cost projections.

Local governments, along with the state and federal governments, have also implemented investment incentives by expediting project approvals and providing seed money for site assessments, tax abatements and low interest loans to participants.

Another significant boon to brownfield redevelopment came with the passage of the Federal 1996 Lender Liability Law, which limits the scope of lender liability associated with environmental cleanups. Previously, a lender could be held liable for environmental contamination if it participated sufficiently in the management of the company that owned or operated on the impacted land. Given financial institutions' aversion to such risk, it was extremely difficult for redevelopers to obtain financing for redevelopment projects. The 1996 law distinguishes innocent lenders from those actually involved in making decisions impacting environmental compliance, and thus paved the way for the increased availability of funding for brownfield redevelopment projects.

These and other related governmental actions signify that brownfield redevelopment is a high governmental priority on a national, state and local level. Government has realized that brownfield redevelopment is important because it puts property back on the tax rolls in a useful, productive way and fosters job creation at what would otherwise remain as neglected and abandoned properties.

**Insurance Industry's Response**

Realizing the unique needs of participants in brownfield redevelopment, insurers have responded to the challenge by

*Continues on page 18 →*

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creating custom insurance packages specially designed for the transfer of real estate that is, or is potentially, contaminated. Included among these types of coverages available are protection against: (1) third party bodily injury or property damage claims arising from on-site pollution conditions; (2) on-site contamination discovered during the policy period; and (3) additional on-site contamination discovered in excess of quantities or characteristics previously known by the insured company. To encourage participation in these coverages, carriers may also provide protection for lenders, contractors and other at risk parties.

**Successful Redevelopment**

The net result of the government incentives and insurance coverage availability has been a resurgence in successful redevelopment efforts. In California, an old steel plant has been reclaimed and redeveloped into the California Speedway. Also in California, a federal courthouse was constructed on a polluted railroad property. A former foundry in Ohio is being redeveloped as part of a river front revitalization project, which will result in “Tool Town”, an educational research park for the machine tool industry.

Metropolitan St. Louis saw the establishment of the Martin Luther King Business Park on a site comprised of abandoned service stations and dry cleaners. Also in Missouri, a former high school that was burdened with asbestos was redeveloped into a shipping center.

**Lowry Air Force Base**

Located in the heart of the Denver metropolitan area, Lowry Air Force Base (LAFB) consists of 2,000 acres donated to the Army Air Corps by the city in 1937 for use as a training base and bombing range. LAFB was operational from 1938 - 1991, at which time the base was closed, presenting the challenge of developing a new use for the occupied land.

The Lowry Redevelopment Authority (LRA) was established in 1991 to formulate a plan for the site. Initial planning involved inventory and analysis of existing environmental conditions. The study revealed the following contamination issues: a plume of groundwater contamination involving spilled jet fuel and de-icing materials which extended over several hundred acres; several buildings containing asbestos; a contaminated landfill; and various hazardous and non-hazardous substances stored on the premises.

LRA remediated the property based on the EPA’s use based standard, anticipating the intended future use of the property. Accordingly, LRA targeted the areas with the least groundwater contamination for residential development, while developing areas with higher levels of contamination for business or parking areas. The landfill was capped and used as a golf course.

A comprehensive insurance program was a critical component of the LAFB project. The policy included five types of coverage: pollution legal liability coverage for third party bodily injury or property damage, or pollution conditions at the site; remediation legal liability coverage to insure against the risk of the discovery of previously unknown on-site contamination; defense legal liability coverage for costs associated with the defense of any claim brought against LAFB under the pollution legal liability portion of the coverage; and remediation stop loss coverage to insure against costs associated with the discovery of additional contamination, greater horizontal or vertical spread of the groundwater contamination, higher disposal costs, or changes in the use based cleanup standards. Blanket environmental coverage is also available for any incident caused by contractors working on the site that may give rise to an environmental claim.

The Lowry Development Plan is a true brownfield success story, made possible by forward thinking individuals, cooperation among diverse groups, the development of an economically viable plan and the availability of a comprehensive insurance program to cover the unique risks of such an undertaking. The result of the LAFB project is the cleanup, development and integration of a classic brownfield into a community that makes continued use of existing infrastructure and other resources.

**The Philadelphia Navy Yard**

The Philadelphia Navy Yard, which was closed in the early 1990’s has historically been used as an industrial facility, with all the attendant contamination issues related to construction and repair of ships. The former Philadelphia Navy Yard presented numerous areas of environmental exposure for Vvaerner ASA, which in 1997 leased a portion of the property for its shipbuilding business.

Among the exposures are contamination from gasoline
stations operated on-site, including fuel tanks, as well as metals, asbestos and PCBs used in association with on-site transformers. In addition, years of operation as a shipbuilding facility, many of those years unregulated in terms of environmental contamination, produced a variety of potential concerns.

Although the Philadelphia Navy Yard redevelopment project is not yet complete, it provides further insight into how government, insurance and a visionary company can work together. This redevelopment project is turning an abandoned property into a profit maker, as well as a substantial source of employment for the region.

Pennsylvania, which was the first state off the mark on the issue of brownfield redevelopment, carefully defines what it considers to be a responsible person under its "Hazardous Sites Cleanup Act". Although Pennsylvania ordinarily follows CERCLA’s definition of a responsible person, it specifically excludes from strict liability a person who merely owns land and was not responsible for the release of hazardous substances.

Further, Pennsylvania provides incentives for redevelopment in the form of financial assistance and liability protection. Pennsylvania’s Land Recycling Program, passed in 1995, is a national leader.

Closed military bases were previously regarded as environmental nightmares; years of producing warships produced potential contamination on numerous levels. However, due to Pennsylvania’s Land Recycling Program, the subject portion of the 1,100 acre ship yard is being redeveloped using a team approach.

Federal, state and local governments contributed $400 million and Kvaerner $45 million to the effort. As part of the deal, Kvaerner negotiated with the state government and obtained a specific agreement that Kvaerner would not be responsible for pre-existing environmental conditions.

Further, Kvaerner obtained a "comfort letter" from the EPA that provided similar assurances. As a result, the company was willing to enter into agreements to resolve the numerous environmental issues pre-existing the deal.

Another substantial factor in Kvaerner’s agreement for the Philadelphia Navy Yard was a customized environmental insurance policy. Philadelphia Shipyard Development Corporation purchased a tailored form of a Pollution and Remediation Legal Liability Policy, which includes coverage against third party claims resulting from sudden and gradual pollution conditions, cleanup costs and legal defense.

Thus, as a result of the agreements with various governmental entities and the prospect of a substantial redevelopment of the site, Kvaerner is able to anticipate completion of its first three ships from the former Philadelphia Navy Yard during 2000. A site that appeared headed for abandonment and disuse will again be a thriving part of the local economy.
SMART SITE, a systems engineering program, has been developed by the Naval Facilities Engineering Command, Southern Division (SOUTHDIV), and the Naval Facilities Engineering Service Center (NFESC). This program has been applied as an innovative methodology at the Naval Industrial Reserve Ordnance Plant (NIROP) in Fridley, Minnesota, and could save the Navy $1.5 million. SOUTHDIV and NFESC contracted with Science Applications International Corporation (SAIC) to implement the first phase of the SMART SITE program.

The program employs a systems engineering approach to identify recommendations for improving the performance and decreasing the cost of remedial action operations (RAO) or long term monitoring (LTM) at a hazardous waste remediation site, thereby accelerating site closure. The first phase of this program, called the Needs Assessment, considers new and improved technology advances, optimal systems designs and system optimization strategies. The objectives of the Needs Assessment are listed in Table 1. Later phases of the SMART SITE program involve pilot phase implementation of the identified recommendations, further evaluation and full scale implementation.

The SMART SITE approach focuses on several areas where major savings may be achieved. The evaluation looks at increasing process automation, including remote monitoring, remote system control and performance monitoring. Information management systems are evaluated, including database integration and performance trends and failures, to assure an accurate record of a system’s effectiveness exists.

Cost savings may be realized from using a proactive regulatory approach, including reducing monitoring frequency, revising cleanup levels and moving toward risk based closure at certain sites. Alternative remedial technologies are evaluated to ensure regulatory compliance and to accelerate site closure.

Good engineering practices are identified to increase a program’s efficiency and may include reliability centered maintenance intervals, effective system control designs and proper equipment sizing. Finally, performance based metrics (measurable performance criteria for RAO or LTM progress) are applied to ensure the system is meeting the goals it was designed for.

Field Application

The SMART SITE Needs Assessment was used to evaluate two phases of the groundwater remediation and monitoring program at NIROP. The NIROP system consist of pump and treat with six groundwater extraction wells and an air stripping system. Phase One of the program consisted of groundwater extraction and discharge of untreated water to the municipal sanitary sewer, with water being treated at the local wastewater treatment plant. Phase Two included the addition of a groundwater treatment facility that treats groundwater and discharges it into the Mississippi River under a National Pollutant Discharge Elimination System (NPDES) permit. Phase Two construction was completed in October, 1998 and operations began in December, 1998.

Since the time the NIROP remediation system was originally designed, many new technological
advances have occurred and previously unknown operational problems have been better defined. This allowed SAIC to take a fresh look at innovative alternatives. The SMART SITE evaluation included several process steps that allowed for a thorough analysis of the NIROP system (Table 2). Each step of this process produced data necessary to optimize the system. The evaluation at Nirop provided solutions to these previously unknown operational problems and uncovered potential system upgrades and ideas for streamlining. Recommendations were then compiled and further evaluated. They were ranked by their estimated cost savings, ease of implementation and their return on investment value.

**Smart Site Analysis**

Eight major program elements were evaluated during this Needs Assessment. They included:

- Remediation treatment technology
- Treatment system design and configuration
- Treatment system O&M functions and costs
- Ongoing sampling and monitoring
- Treatment system equipment and controls
- System monitoring
- Data acquisition and reporting
- Future remediation systems.

No apparent major problems or deficiencies were found in the effectiveness of the pump-and-treat technology at NIROP. This technology (when compared with hydraulic containment barriers, reductive reaction walls, air sparge curtains and bioremediation) was deemed the most appropriate for the site-specific conditions.

The system was further evaluated for hydraulic capture and mass removal efficiency, as well as system scaling and fouling problems. The treatment system design evaluation included looking at the individual extraction well designs, use of an existing bypass line to the sanitary sewer, influent pumping system for extracted groundwater to the air stripping system, effluent pumping from the air stripping units and compliance monitoring, and anti-scaling system.

The O&M functions and cost were evaluated and included looking at current preventive, predictive, and unscheduled maintenance activities, the tray aerator disassembly and cleaning process, operation consistency, and system automation.

System sampling and monitoring requirements were closely evaluated. This included looking at the existing sampling and monitoring requirements such as frequency, number of sampling locations, and analysis methods. Wellhead controls and monitoring were evaluated as well, including existing controls and automation.

The entire system has substantial control and monitoring capability, but was only being used to a limited extent. The Supervisory Control and Data Analysis (SCADA) system (including its location and accessibility) was evaluated for possible upgrades to increase the automation and efficiency of the NIROP system. The data acquisition and reporting functions of the system were evaluated as well as the ability of the system to analyze the contaminant capture efficiency over time.

Finally, in consideration of the future needs for groundwater treatment at NIROP, SAIC looked at future needs for expansion of the remediation system. They looked at utilizing the full capacity of the existing system for treating possible future sources on the site, as well as the use of in-situ or ex-situ treatment technologies. These treatments would be used concurrently with the existing pump-and-treat system. This evaluation took into account the expansion of the extraction and air stripping system, system controls and automation, and other equipment currently being used on site.

Continues on page 22 ➔
Results of Smart Site Analysis

Once the remediation treatment technology and each element of the remedial program were evaluated, potential opportunities for cost savings or performance improvement were identified. Eight specific recommendations were presented to optimize the NIROP RAO system performance that, if implemented, could result in an estimated savings of approximately $160,000 per year.

- Upgrading the current well field at NIROP by installing two additional extraction wells, reducing groundwater extraction rates, and discontinuing pumping of an existing extraction well, will increase system performance.

- Untreated water may be diverted to the sanitary sewer by adding a bypass line that may be used during system downtime, keeping the extraction system on-line.

- The need for discharging treated water by pumping may be eliminated by using gravity discharge of treated water, decreasing power costs.

- Electrical power requirements may be further reduced by modifying influent and effluent pumps.

- System operations and maintenance (O&M) costs would be reduced by implementing a streamlined preventative O&M schedule.

- Monitoring costs would be reduced by streamlining the sampling and monitoring program, including reducing sampling locations and frequency, and modifying the current analytical method.

- Finally, further cost savings would result from upgrading the wellhead monitoring system, and increasing automation of the system operation and reporting functions, including the addition of automated system control, data collection, and reporting functions.

<table>
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<tr>
<th>Preliminary Recommendation</th>
<th>Estimated Yearly Savings</th>
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<tr>
<td>Well Field Upgrade</td>
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<tr>
<td>Bypass to Sanitary Sewer</td>
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<tr>
<td>Gravity Discharge of Effluent to Storm Sewer</td>
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<tr>
<td>Influent and Effluent Pump Upgrades</td>
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<td>Streamline Sampling and Monitoring Program</td>
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<tr>
<td>Wellhead Monitoring Upgrade</td>
<td>$15,400</td>
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<tr>
<td>Control System Upgrade and Automated Reporting</td>
<td>$16,500</td>
</tr>
<tr>
<td><strong>Total Yearly Cost Savings</strong></td>
<td><strong>$162,091</strong></td>
</tr>
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</table>

Table 2: Recommendations and potential savings from SMART SITE analysis.

The largest cost savings may be achieved at NIROP by implementing the well field upgrade recommendation. This will increase the mass removal efficiency, reduce fouling and scaling of the wells, and reduce well maintenance costs alone by an estimated 10-30% per year.

Furthermore, reducing the frequency and number of monitoring wells sampled and by changing analytical methods would produce the easiest and quickest savings. Each recommendation and its potential savings is listed in Table 2.

The SMART SITE evaluation identified numerous alternatives and modifications that can reduce the cost of the RAO program at NIROP. The potential overall cost reduction represents 20% of the average yearly O&M costs. The net present value of the savings based on a 20 year life could reach $1.5 million.
Focus on:

Associations

• Air & Waste Management Association
  1 Gateway Center, 3rd Floor
  Pittsburgh, PA 15222
  Phone: 412-232-3444
  Fax: 412-232-3450
  Website: www.awma.org

• American Association for Laboratory Accreditation
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  Frederick, MD 21704
  Phone: 301-644-3248
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• American Consulting Engineers Council
  1015 15th St. N.W. #802
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  Phone: 202-347-7474
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• American Petroleum Institute
  1220 L Street N.W.
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  Phone 202-682-8000
  Fax: 202-682-8154
  Website: www.api.org

• American Society for Testing and Materials
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  Website: www.astm.org

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• ASFE
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  Fax: 301-589-2017
  Website: www.asfe.org

• Association for Engineering Geologists
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  College Station, TX 77843-3115
  Phone: 409-845-0142
  Fax: 409-862-7959
  Website: www.aegweb.org

• Biotechnology Industry Organization
  1625 K Street N.W. #1100
  Washington, D.C. 20006
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  Fax: 202-857-0237
  Website: www.bio.org

• Environmental Assessment Association
  1224 N. Nokomis N.E.
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  Phone: 320-763-4320
  Fax: 320-763-9290
  Website: http://iaei.org/eaia.html

• Geosynthetic Materials Association
  A division of: Industrial Fabrics Association International
  1801 County Road B W
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  Phone: 612-222-2508
  Fax: 612-631-9334
  Website: www.ifai.com

• National Association of Environmental Professionals
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  Fax: 904-251-9901
  Website: www.naeap.org

• Petroleum Equipment Institute
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  Tulsa, OK 74101
  Phone: 918-494-9696
  Fax: 918-491-9895
  Website: www.peinet.org

• Soil Science Society of America
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  Madison, WI 53711
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  Fax: 608-273-2021
  Website: www.soils.org/ssa

Soil & Groundwater August/September 1999 23
Remedial actions for soil and groundwater contamination pose increasingly complex challenges for environmental managers. A greater variety of contamination problems are being defined and innovative technologies are emerging as potential alternatives to conventional technologies. Meeting these challenges requires environmental managers to balance information about technology performance and risk reduction with fixed or limited, budgetary resources, stakeholders' concerns and regulatory constraints.

In response to these information needs, a Technology Evaluation Framework has been designed for systematically comparing conventional and innovative remediation technologies on criteria relevant to technology selection and deployment for voluntary or regulatory agency mandated cleanups. Developed from an extensive dialogue with environmental managers, supplemented by the experience of individual team members and reviews of technology selection and deployment activities, the Framework integrates eight criteria relevant to the technology selection and deployment process.

A pilot application was performed utilizing data from three Department of Energy (DOE) sites and one Department of Defense (DOD) site. Trichloroethylene (TCE) was used for the benchmarking exercise because TCE contamination of soil and groundwater is a pervasive problem at DOD installations, across the DOE nuclear weapons complex, and private sector sites. The Norton Air Force Base site in California is used here to illustrate the Framework.

James L. Regens and Donald G. Hodges are with Tulane University Medical Center, New Orleans. Patrick L. Wilkey and Eric Zimmerman are with Argonne National Laboratory, Argonne, Ill. Anthony Q. Armstrong is with Oak Ridge National Laboratory, Oak Ridge, Tenn. Linda Kelley is with CB Consulting, San Luis Obispo, Calif. Timothy A. Hall is with ManTech Environmental Corporation, Chantilly, Va. And Eugene A. Hughes is with Erin Engineering and Research Inc., Walnut Creek, Calif.

Overview of the Framework

The Technology Evaluation Framework provides a standardized methodology to integrate diverse factors influencing the selection and deployment of environmental technologies. Encompassing an array of factors ranging from technical performance, life cycle costs and risk to future use, eight criteria with measurable indicators are employed to assess the capability of a technology or suite of technologies to address environmental restoration problems on a site specific basis (Figure 1).

The Technology Evaluation Framework enables environmental managers to systematically compare innovative and conventional technologies in terms of meeting remediation goals. Because the Framework does not employ a series of a-priori weights for each criteria, it identifies tradeoffs among the eight criteria based on site specific needs, such as temporal or physical constraints, schedule demands and funding profiles.

To complete the Framework, the user needs to assemble site background data and define working assumptions, including deployment scenarios for each of the technologies being evaluated, to produce the
information required to generate ratings on each indicator for the various criteria. The completed Framework provides a documented, reproducible evaluation summarized on a rollup sheet, which can be updated as new information becomes available.

Environmental Setting

The environmental setting at Norton Air Force Base is an unconsolidated deep aquifer located in a high desert region. The surrounding area consists of a gently sloping alluvial plain developed by coalescing alluvial fans extending from the mountains to the northeast. The local topography of the valley floor is due primarily to erosion and the development of stream channels. The surface slopes to the southwest at approximately 30-50 ft/mile, with topographical elevation above mean sea level varying from a maximum of 1,200 ft along the eastern boundary to 1,040 ft along the western boundary.

The soils are generally quite permeable and exhibit limited potential for runoff and water erosion. The geological setting is typical of an alluvial fan environment. The upper aquifer, an interval from 75-200+ ft, consists predominantly of sands and gravels, with intercalated silt and clay lenses from 1-5 ft thick.

The uppermost hydrologic unit is the confining member that overlies the upper aquifer. The actual extent of confined water varies, depending on recharge and other factors. The confining member locally supports perched water zones that occur at depths from 30-60 ft. The clay layers that support the perched water are not laterally continuous; locally, there may be one, two or more perched zones. The perched water zones can only be maintained if recharge water is available, and many of the perched wells previously installed have gone dry.

Soil and Groundwater Contamination

Three source areas exist for TCE contamination. Area One is an industrial waste disposal system/underground storage tank farm. Area Two is a removed cleaning solvent tank farm. Area Three consists of underground storage tanks for waste oil (southeast corner), heating fuel/waste oil (southwest corner) and maintenance operations such as plating, paint and machine shops. TCE was detected in Area One soil samples from the surface to a depth of 30 ft at concentrations ranging from 36-43,000 µg/kg. At Area Two, TCE was detected in soil samples collected from the surface to a depth of 90 ft at concentrations ranging from 8-1,900 µg/kg. TCE was detected in soil samples from Area Three from the surface to a depth of 60 ft at concentrations ranging from 1-10,000 µg/kg. (Figure 2)

TCE also has been detected in groundwater samples collected from monitoring wells screened in the top, middle and lower portions (>200 ft) of the upper aquifer at concentrations ranging from 1-550 µg/L (Figure 3). The lateral extent of TCE affected groundwater is defined except for the down gradient margin.

Groundwater containing TCE has migrated off site. The plume’s eastern margin is elongated, indicating the plume originated from a series of dispersed sources and not from a single source. The plume’s up gradient and lateral have been defined based on the monitoring well network. The plume continues in a southwesterly direction, toward the site boundary.

The farthest down gradient wells (>1,000 ft beyond the site boundary) exhibit TCE concentrations exceeding the maximum contaminants level (MCL). The bottom of the plume appears to be less than 200 ft deep throughout most of its extent, except along its axis, where the MCL is still exceeded.

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Technology Deployment Scenarios

A comprehensive remedial scenario for Norton AFB might include deploying the technologies discussed below singly or in combination, although other technologies might also be applicable. Long term groundwater quality monitoring also probably would be part of remedial actions targeted at subsurface contamination. To compare individual soil and groundwater remediation technologies, only long term monitoring activities specifically associated with a particular technology’s deployment are considered.

Groundwater Containment

Groundwater containment could be pursued with 60 extraction wells for pump-to-contain, 200 ft deep with a 10 inch diameter and 75 ft stainless screen, located at the leading edges of the TCE plume. Two crews of four operators each would construct the wells in three months. Wells would pump 200 gpm total. The influent TCE concentration would be 5 mg/L. Double contained conveyance piping would extend 5,000 ft, and the contaminated groundwater would be treated using air strippers and vapor activated carbon (VAC) with granular activated carbon (GAC) polishing. The system would operate for 30 years with uniform mass removal over time manned by a full time operator to maintain and monitor the system. A slurry wall would not be applicable because depth constraints exceed the limits of its applicability (+1 120 ft). In situ groundwater management also was not applicable due to depth constraints (limit of applicability, 50-60 ft).

Groundwater Treatment

Eighty five extraction wells for groundwater treatment using pump-and-treat could be constructed within four months by two crews of four operators each and would be contained within the TCE plume. These 200 ft deep, 10 inch diameter wells would have 75 ft stainless screens. The wells would pump 200 gpm, and the influent TCE concentration would be 5 mg/L. Conveyance pumping would extend 6,000 ft, and the contaminated groundwater would be treated using air strippers and VAC with GAC polishing. The system would be set up to operate for 30 years with uniform mass removal over time. Two operators would remain on site full time to maintain and monitor the system. Funnel-and-gate and LASAGNA™, an innovative technology, are not applicable because of depth constraints.

Soil Containment

A slurry wall could be constructed around the TCE source and would measure 1,000 ft long, 75 ft deep, and three ft wide. The wall would be constructed through silts, sands and gravels, and the on site soils would be amended with import fill and bentonite. The depth to groundwater is five ft at the construction site. The slurry trenching would be completed in segments; 30% of on site soils would be hauled for disposal to a site two miles away. The operators would complete construction in approximately two months. Alternatively, a RCRA cap with a paved surface could be constructed over the source term area, which is 1.5 acres, by eight laborers in 1.5 months.

Soil Treatment

Using dig-and-haul, the excavation volume would be 150,000 yd³. The transportation distance would be 20 miles, and the duration of digging and hauling would be seven months. This would be accomplished using an excavating and loading crew of 10 laborers and the transportation crew would use 80 20-ton trucks.

Low Temperature Thermal Desorption (LTTD) could be employed with eight laborers to excavate and load soils into the treatment unit. Treatment would require seven months using tsc low temperature treatment units, with off gas treatment.

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Figure 4: Environmental technology evaluation data sheet - groundwater treatment

NOTE: For those indicators that are color-coded, green indicates the technology has a desirable rating for that attribute, yellow indicates a medium rating, and orange indicates an undesirable rating.
A volume of 150,000 yd³ would be treated, and the treated soils backfilled on site. Alternatively, a crew of four laborers could build a Soil Vapor Extraction (SVE) system with 20 4-inch diameter vents with a 10 ft screen in the vadose zone to 75 ft. Construction of the vents would require two months; plant construction would require two weeks. Five 2-inch injection vents would be installed with a 10 ft screen. There would be PVC construction with stainless casings. Conveyance piping would extend 500 ft, and the flow rate would be 300 standard ft³/minute.

Influent TCE concentration would be 1,000 µg/L soil gas. Vapor phase carbon treatment would result in uniform mass removal over time. This system would operate for five years, with one person remaining on site 25% of the time.

Results

Pump-to-contain is the only groundwater containment technology evaluated that is suitable for Norton AFB. Its effectiveness and implementability were rated medium because of problems caused by the contamination's depth. The life cycle cost for pump-to-contain was estimated to be $9.8 million. The technology was rated medium in relative risk reduction since some of the pathways would remain. No problems were foreseen regarding process residuals.

Future use was rated low because restrictions are likely; pump-to-contain has been permitted in this jurisdiction. Stakeholders are concerned about performance, cost, natural resource damages and tribal issues.

Like groundwater containment, the pumping technology (pump-and-treat) is the only technically feasible groundwater treatment technology for the site (Figure 4). Technical performance ratings for funnel-and-gate and LASAGNA™ were low because of the depth constraints of the site and were not evaluated further.

Relative risk reduction for pump-and-treat was medium since some pathways and some of the contamination would remain. Total life cycle cost was estimated at $12.7 million.

The slurry wall technology for soil containment was rated low in terms of effectiveness and medium on the other performance indicators because of the plume's depth. The RCRA cap was rated high for all technical performance indicators, except for effectiveness which had a medium rating.

Life cycle costs were $1.8 million for the slurry wall and $720,000 for the RCRA cap. Avoidance of future use restrictions was rated medium for the slurry wall and low for the RCRA cap. Stakeholders concerns include performance, cost, natural resource damages, and tribal issues.

Technical performance ratings for soil treatment were identical, except for SVE, which was considered to have medium effectiveness (Figure 5). This resulted primarily because of the difficulty in applying it at the required depth.

Life cycle costs varied significantly with dig-and-haul as the most expensive option with a total cost of $73 million, primarily from its high capital costs. LTMD total costs were $30 million, while SVE total costs were only $1.9 million.

For risk, dig-and-haul was rated high for relative risk reduction, while LTMD and SVE were rated medium. LTMD was rated medium for exposure risk to workers because of the nature of the process involved, while dig-and-haul poses medium risks to the public from the off site transportation of hazardous material.

Future use was rated high for dig-and-haul and LTMD because the contaminant would be removed, allowing unrestricted land use, but medium for SVE. Stakeholder concerns include performance, costs, process residuals, natural resource damages and tribal issues associated with the technologies.

The results of a pilot application of the Technology Evaluation Framework provide significant insights into the Framework's ability to support decision making about site remediation options.
Monitoring Alerts by Phone
Antx Inc., Austin, Texas, has developed the ADAS DiaLog alarm monitoring and notification system that automatically phones or pages up to 16 separate numbers from a single or series of alarm conditions. DiaLog continues to call, giving user-recorded messages, until all alarms are acknowledged.

Reduce Costs with Fewer Holes
Solinst Canada Ltd., Georgetown, Ontario, offers the Waterloo Multilevel Systems, requiring fewer holes, and reducing purge volumes. Minimized annular space reduces field times for groundwater sampling and taking pressure readings. Both permanent and removable packers ensure long term integrity of the seals between monitoring zones. Removable systems allow re-use of the system at new locations or zones and makes decommissioning easy.

Compact Spectrometer
Perkin-Elmer, Norwalk, Conn., offers the Lambda EZ150™ ultraviolet/visible spectrometer. This is an easy to use instrument that ensures reliable measurements for a multi-user laboratory environment.

With any two wavelengths defined, Absorbance ratios and Absorbance differences ratio can be measured and reported with the press of a button. Additionally, self diagnostics verify correct operation and optical performance.

Fast Test for Water Samples
SPEX CertiPrep, Metuchen, N.J., introduces the Certi-Strip™ Water Quality Test Strip. The Certi-Strip is a fast, easy method for testing water samples off-site or in the laboratory. Certi-Strips available include: Bromide, Free Chlorine, Total Chlorine, Iron, Iodine, Nitrate Nitrogen, Nitrite Nitrogen, Peroxide, pH/Alkalinity and Total Hardness.

New AC/DC Specialty Gas Monitors
CEA Instruments Inc., Emerson, N.J., offers the TG-KA series of portable toxic gas detectors. These detectors are direct reading, compact instruments with digital display that use patented gas membrane galvanic sensors. Available for Formaldehyde, Ozone, Hydrogen Chloride, Phosgene, Hydrogen Fluoride, Phosphine and others.

Detection Before Reaching Water

Stand-Alone Datalogger
Campbell Scientific Inc., Logan, Utah, offers the CR510 Basic Datalogger. This is a stand-alone measurement and control unit for remote unattended applications requiring a small number of sensors. The CR510 operates on 12Vdc, consumes little power, and accepts a variety of telecommunications interfaces including RF, phone, cellphone and satellite. An onboard instruction set allows measurements to be processed and stored as hourly and daily summaries.

Gas Detection Device
Gas Tech Inc., Newark, Calif., announces the FX-SMT Transmitter Series as being UL approved. All versions are suitable for installation in Class I, Division I Groups B,C & D hazardous locations. The FX-SMT line of transmitters come standard with non-intrusive calibration which eliminates the need to declassify hazardous areas.
Fixed Air Burner
Eclipse Combustion Inc., Rockford, Ill., offers the new ThermAir burner. The device is a nozzle-mixing burner with a packaged air blower designed to fire with fixed combustion air over a wide gas turndown range (30:1). Fixed air operation plus integral gas and air orifices makes for quick setup and adjust.

Gas Detection System
Mil-Ram Technology Inc., San Jose, Calif., offers the TOX-ARRAY 2000, a six channel controller. The chemically selective Toxic, LEL and O₂ sensors do not react with air, are not sensitive to changes in temperature, humidity or pressure and stay awake when gas is absent. Recovery is less than 15 seconds even when exposed to high gas levels.

Low Flow Rate Electromagnetic Meters
Water Specialties, Porterville, Calif., offers the Ultra Mag™ electromagnetic meter as an accurate metering device available for wastew and sludge flows. Due to its ability to handle low flow rates and its consistent repeatability ratio, it is suited to measuring the flow rates of not only water and wastewater, but also the thickest and stickiest slurries and sludges. Without moving parts in the flow tube, the meter does not require clean, pure water to operate, and is not sensitive to foreign matter in the flowlines.

Sludge Stabilization
Colloid Environmental Technologies Co., Arlington Heights, Ill., has introduced a new line of products called LiquiSorb® for sludge stabilization and solidification. LiquiSorb products are suitable for hazardous and non-hazardous liquids, wet industrial sludges and dredging wastes. LiquiSorb creates a dry, stable waste that passes Paint Filter testing and may reduce leaching of contaminants to pass TCLP testing.

All-Plastic Flow Switch
Hayword Industrial Products Inc., Elizabeth, N.J., offers the Model 2600 Flow Switch. Pumps in corrosive, ultra-pure or other applications can now be easily and cost effectively protected from running dry or pumping against a closed valve. The flow switch can protect pumps installed in either plastic or metal pipelines for 1/2" up to 8" size.

Containment Pallet
UltraTech International, Jacksonville, Fla., introduces the Ultra-SpillKing containment pallet, featuring removable deck and 4-way forklift entry. The deck can be easily lifted from the sump by a forklift to transport drums to specific locations. Rugged, polyethylene construction features a 6,500 pound static load capacity.

Submersible Aerator
Aeromix Systems Inc., Minneapolis, Minn., announces a new feature of the Hurricane Submersible Aerator. The feature is a submersible motor specifically engineered to Aeromix specifications. The motor is dry running, self-cooled, include high reliability moisture detectors and thermal protection, are explosion proof, and feature commercially available bearings and seals.

High Accuracy Temperature Probe
Unidata America, Lake Oswego, Ore., offers the Model 6507D as a new high accuracy thermistor type temperature probe intended for environmental temperature monitoring. Typical applications include temperature measurement in air, water, soil, snow and ice. The sensor is sealed in a stainless steel housing and can be submerged in water up to a depth of up to 10 feet.

Continues on page 30 →
What's new, from page 29

Rock Drilling System
Vermeer Manufacturing Co., Pella, Iowa, has developed the Vermeer® ROCKFIRE™ AS6 Rock Drilling system. This is a steerable pneumatic rock drilling system engineered to penetrate and steer through difficult rock formations. The ROCKFIRE system incorporates the Vermeer NAVIGATOR™ horizontal direction drill with a pneumatic down hole hammer, air compressor and foaming agent to clean cuttings out of the bore path.

Write in 846

New Chloride Dioxide Test Kit
CHEMetrics, Calverton, Va., announces the new Chloride Dioxide Water Analysis Test Kit. The kit comes packaged with the patented technology, the self-filling ampoule. Each ampoule contains a unit dose of liquid reagent sealed under vacuum, which eliminates the need to measure and mix chemicals, simplifies testing, and virtually eliminates reagent spoilage. Testing time is approximately one minute.

Write in 847

Automatic Magnetic Drain
Kaeser Compressors, Fredericksburg, Va., offers the Kaeser AMD-6550. The unit is manufactured with a large orifice drain valve to eliminate clogging and costly maintenance repairs. The AMD-6550 features rugged and lightweight construction and a fluid level gauge for easy monitoring of fluid levels. The magnetic flux ensures the condensate chamber is completely separated from the control mechanism providing reliable operation.

Write in 848

Three-Layer Garment Construction
Kimberly-Clark, Roswell, Ga., introduces an enhanced fabric structure for KLEENGUARD® Ultra Protective Garments. The new construction is a three-layer laminate, with a microporous film interior layer and outer layers made of a copolymer of polypropylene and polyethylene.

Write in 849

Geomembrane System
Seaman Corporation, Wooster, Ohio, offers the XR-50 Geomembrane System, proven to withstand harsh environments and contaminants. From subzero temperatures to blistering UV rays. From wastewater to hydrocarbon contamination. The 30-mil XR-5 material is stronger than polyethylene of twice the thickness.

Write in 850

Clear PVC Pipe
New Age Industries Inc., Willow Grove, Penn., announces the availability of clearer Clear-40® schedule 40 PVC pipe. The improved formula makes it easier to view materials within the pipe. The pipe offers corrosion resistance, high tensile strength and a smooth interior for uninterrupted flow.

Write in 851

One-Step Bioremediation
Royer Industries, Kingston, Penn., introduces its new line of bioremediation soil shredder-mixers. The Royer Remediators utilize a simple one-step process that shreds contaminated soil while injecting a microbe/water/nutrient solution directly into the discharge stream.

Write in 852

Patented Microbial Product
Osprey Biotechnics, Sarasota, Fla., has introduced Petrox, a patented microbial product designed for fast, effective bioremediation of petroleum hydrocarbons. Petrox is composed of patented strains of live vegetative microorganisms that are freeze dried and stabilized.

Write in 853

Aboveground Storage Tank Software
The Steel Tank Institute, Lake Zurich, Ill., has developed Fireguard® QuickSpec 4.0. This interactive CD-ROM software allows engineers, contractors and end users to easily and quickly develop accurate, complete, protected storage tank specifications.

Write in 854
Relocatable Safe Storage Building
Safety Storage Inc., Hollister, Calif., announces the availability of their new Model 2410FS FireShield™ prefabricated, relocatable building. The building is designed for safe storage, handling and use of chemicals and hazardous materials.

Intelligent Subsurface Imaging System
Sensors & Software, Mississauga, Ontario, introduces the Noggin Smart Cart, providing artificial intelligence for subsurface imaging. The device uses a Noggin ground penetrating radar (GPR) system. The cart enables users to easily locate areas of subsurface interest without a-priori information.

Removal of Grease, Oily Slime or Crud
Abanaki Corporation, Chagrin Falls, Ohio, offers the Grease Grabber®, a mechanical belt skimmer. The unit’s 8-inch wide belt breaks the surface tension of the water attracting heavy grease and oil. Textured pressure rolls pull the belt over an idler pulley and through the angled wiper blades where grease and oil are removed from both sides of the belt.

DNAPL and LNAPL Recovery Pumps
PumpWorks Inc., Plymouth, Minn., announces the PW2000 series of UL Listed non-hazardous and UL Listed Explosion Proof Dual Solenoid Piston Pumps. These compact in-line pumps can fit in 4-inch wells and are excellent for free product recovery. This is achieved because flow can be controlled to the amount of contaminant entering the well and the pumping action does not mix groundwater and free product.

Waste Eradicators
Micro-Bac International, Round Rock, Texas, announces Mega-Bac X. The product is specially formulated as a granulate or liquid concentrate to eliminate the majority of contaminants in soil and groundwater cleanup. The products are all natural and work by completely digesting harmful toxins, solids and waste into harmless substances such as carbon dioxide and water.

Highly Portable Spectroradiometer
Analytical Spectral Devices Inc., Boulder, Colo., introduces the FieldSpec® Pro, a highly portable UV/VIS/NIR spectroradiometer. Featuring a unique backpack design for fast and easy transport, FieldSpec Pro combines the flexibility and durability of a field instrument with laboratory accuracy.

ANSI Pump Product Line
Goulds Pumps, Seneca Falls, N.Y., has introduced a complete line of heavy duty, magnetically driven, lined ANSI process pumps, the 3298 Series. The 3298 Series liquid end parts are lined with a thick layer of Tefzel® for universal corrosion resistance. This provides an impenetrable barrier against leakage.

Density Separator
Vortex Ventures, Houston, Texas, introduces the Spintop Hydrocyclone. The device is a density separator for separating solids from liquid. It is ideally suited for use in soil washing regimes. The Spintop Cyclone will perform a two-fold function of scrubbing contaminated soil and separation of fine and medium solid particles.

Economical Monitoring Systems
Sentex Systems Inc., Fairfield, NJ., offers community water systems with economical monitoring systems to help alleviate safety concerns and provide high quality risk assessment tools. Sentex Systems offers a choice of on-site, on-line systems that measure and monitor VOC contaminants utilizing a unique G.C. purge and trap technology.
There is no doubt that environmental forensics is an evolving discipline. While the genesis of the term "environmental forensics" remains debatable, it is probably safe to say that you rarely if ever heard of the subject 5 years ago. And today, if you are in the site investigation or environmental law business, you've heard that this practice is used frequently to assist investigators in better understanding nature, extent, ownership, and allocation of site contamination. In this rapidly growing field, where substantial financial liability and even criminal penalties for site contamination can rest on the result of a environmental forensic investigation, it is absolutely essential that the best science, engineering, research, and law be brought to bear.

Because it is an emerging discipline, forums where meaningful intellectual presentation, discussion, and debate on subject matter relevant to environmental forensics takes place are rare. Enter the International Business Communications (IBC) Forum on Environmental Forensics.

I recently had the distinct honor to co-chair the 2nd Annual Executive Forum on Environmental Forensics held June 24-25, 1999 in Washington, D.C. Fittingly, as is preached often in this column, the theme of the conference was "integrating advanced scientific techniques for unraveling site liability". This article is a brief review of this very successful and important conference.

Approximately 100 delegates composed primarily of site assessment and environmental law professionals gathered for this two day meeting to listen to the advice, experiences, and anecdotes of twenty-two speakers. All the speakers were bona fide experts in scientific, records research, and legal aspects of environmental forensics.

Broadly, the Forum was well balanced among technical, records/historical research, and legal presentations. Within each subject area, well prepared presentations on theory and practice were given. For the first time in this reviewer's memory, the majority of the presentations included excellent cases studies in the application of environmental forensics.

Technical Advancements

The cornerstones of environmental forensics are measurement, interpretation, and visualization techniques. These provide insight into the detailed nature of site contamination, transport of those contaminants to and from a site, the likely sources of contamination, and allocation of ownership and responsibility of in-place contamination.

Several exciting and compelling presentations were given that showcased the dramatic advancements being made in measurement techniques for forensic investigations.

Examples include the work of Dr. Scott Stout (Battelle), who talked about the utility of chemical biomarkers in differentiating and tracking the fate of similar or highly weathered petroleum products - a problem many investigators face at sites where in-place petroleum is either highly weathered or potentially arises from several similar sources.

Jim Davidson (Alpine Environmental) provided an exceptional overview of the history, chemistry, and behavior of the gasoline additive MTBE. Once the unique properties of this chemical are understood, that information can be used in environmental forensic investigations of the source or sources of modern gasoline spills and releases.

Dr. Greg Douglas (Arthur D. Little Inc.) discussed the use of gas chromatography isotope ratio mass spectrometry. This novel tool that has the potential to differentiate among sources of individual chemicals (e.g., water soluble components of petroleum such as benzene, toluene, etc. or discrete industrial chemicals like trichloroethylene) based on the stable carbon 13/12 ratio of the molecule of interest. This has been a
heretofore impossible task prior to the development of this unique instrument.

An excellent presentation by Dr. Daniel Stephens (Daniel B. Stephens & Associates, Inc.) focused on scientific methods for allocating mass, volume and toxicity of in place contamination. He suggested the bases for equitably and defensibly allocating costs of remediation and cleanup when several responsible parties have contributed to site contamination.

A too often underutilized technique, air photointerpretation and photomicrogrammetry, was presented as a compelling environmental forensic tool by Wayne Grip (Aero-Data, Corporation). He provided superb examples of how historic photography and site information is used to build detailed historical depictions of sites. Through the use of advanced computer imaging software, this information can be used to give remarkable photo-historic 'tours' of sites.

Finally, Dr. James Brueya (Freidman & Brueya, Inc.) reminded the audience of the quality assurance and technical validation processes that must be followed in order to make any environmental forensic data unimpeachable in the eyes of lay or legal decision-makers.

Mr. Steven Dickenson (Law Offices of Steven L. Dickenson) gave an excellent overview on the admissibility and effective use of experts and expert evidence in environmental forensic lawsuits. His talk focused on the current standards for expert admissibility and guidelines for choosing, communicating with, and managing the expert.

On a related subject, Mr. Scott Blauvelt (Earth Science Consultants, Inc.) spoke of preparing the expert scientist and engineer for testimony. This talk presented a wonderful perspective from a technical expert who understands the law and the legal process. Mr. Blauvelt discussed how experts are perceived by juries, judges, and opposing counsel, and how they should be selected in light of these perceptions. His succinct guidelines for the preparation of the expert report was invaluable information for the investigators and potential experts in the audience.

Finally, Mr. Steven Adams (Gardere & Wynne) presented a compelling and convincing case study in the effective use of environmental forensics in the settlement of a major class action suit, the Glenn Pool oil field pollution case in Tulsa, Okla. In his presentation, Mr. Adams hit on virtually every legal and practical aspect of the use of experts, from the very rigid admissibility standards pertinent to the case, to the more subtle but important selection of experts. And the most effective means of information presentation by these experts in a local Tulsa district court.

The Legal Viewpoint

Environmental forensic data and the opinions that investigators draw from such data are often used to resolve legal disputes about the sources and responsibility for site contamination. Environmental forensics investigations, and those experts that conduct and opine on those studies, must meet certain legal litmus tests for admissibility in court.

At the same time, the manner in which environmental forensics investigations are planned, conducted, and presented should follow practical standards, such that the data garnered and the opinions drawn from a study are understood and deemed credible by lay decision makers.

A number of talks by experienced environmental lawyers addressed these subjects. These presentations were extremely important for the site investigators and the potential experts in the audience. The fundamental of the law as they pertain to expert testimony are rarely considered in the planning of site investigations. And once a case moves to litigation, it is often erroneously assumed that the technical expert understands the laws that govern the acceptance standards for his or her qualifications, or the admissibility of their studies.

In this light, several excellent presentations on the fundamental aspects of the law vis a vis environmental forensics investigations were presented in the Forum.

Mr. Kirk Sniff (Strasburger & Price) addressed the evolution of causation, and the role that environmental forensics plays in proving or rebutting the basic elements of causation, particularly in toxic tort litigation.

Integrating Science, Research, and the Law

I was delighted to hear virtually every technical and legal expert agree that the modern environmental forensics investigation hinges on the coordinated work of a team of experts. In the past, expert work in site investigation has perhaps been too reliant on a single "Jack-of-all-trades" expert, or a loose assemblage of experts not working in a coordinated fashion.

Clearly, the agreement amongst the experts at this Forum was that the success of an environmental forensics investigation depends on selection of forensic experts in all the critical technical areas. (Contaminant chemistry, geology/modeling, data visualization, historical records research to name a few.) And then managing those experts in an integrated fashion. The synergy and defensibility of the resulting work products and testimony outdistance the quality of less prepared cases.

If you are a site investigator or environmental lawyer who deals with advanced site assessment or toxic tort issues, The International Business Communication IBC forum on Environmental Forensics should be on your list of "must attend" meetings. You can get information about next year's IBC Forum on Environmental Forensics by contacting Ms. Abby Votto at International Business Communication (508-504-5404). I hope to see you at next year's meeting.
Looking out over the Eastern Highlands of Zimbabwe we see hills, trees and fields dotted with houses. Within this landscape there are hundreds of soils formed and forming from slightly different parent materials and in slightly different climates. Most of these soils are sandy with no silt and little clay. However, there are small areas of soil with high clay contents. Contamination in this part of Zimbabwe will mean contamination of several to dozens of different soils, each with different characteristics. Mapping the area is the best first step in the cleanup of such contamination.

A map is any representation of the earth’s surface as it would look when viewed from above (technically any object could be mapped). Mapmakers always face three important problems. One is shape; the other two are related to size. The first is the fact that the earth is round and maps are flat. A contaminated site is usually so small that the curvature of the earth is insignificant. The second and third problems are related to the size or scale of the map to be produced.

On the first hand, one wants a map of the whole area. On the other hand, a great deal of detail is desired. One might say that there is an inverse relationship between scale and detail. As the detail increases the area which can be shown decreases. On the other hand the greater the area the less the detail. Mapmakers do not talk about maps in terms of size but in terms of scale.

Scale
Maps may be said to be of small, medium or large scale. Small-scale maps show large areas, include little detail, and have large denominators in the representative fraction (R.F.). Large scale maps show small areas in greater detail and have small denominators in their R.F. It may help to avoid confusion by remembering that Ω is a smaller fraction than 1/100.

Small scale maps would have R.F.s less than 1:1,000,000, medium scale maps have R.F.s between 1:100,000 and 1,000,000 and maps with R.F.s less than 1:100,000 would be large scale maps.

In many remediation situations, both medium and large scale maps are required. Not only are large or very large scale maps of the immediate area of contamination needed, but also smaller scaled maps so that features relevant to contaminant movement or potential movement can be seen. Features such as water sources, lakes, ponds, rivers etc. but also slope and other features in the immediate area, which will affect remediation efforts, must be known.

Types of Maps
In addition to scale, maps can be grouped into almost innumerable types. Among these are detail maps, large area maps, distribution maps and sketch maps.

Detail maps show large scale (cover small area of land). The largest possible scales are called cadastral maps. These show individual roads, houses, and farm plots. This type of map has been used for taxation for many centuries.

Another map of this type is the topographical map which shows physical features, specifically altitude, along with drainage ways, forest and man made features. Because of its moderate size and accurate information, this type of map is particularly useful in working with contaminated areas.

Atlas maps also cover large areas of land. They may cover an entire country or continent and even the whole world. The information on such maps is never detailed as compared to cadastral or topographical maps. Atlas maps and any others which cover large areas of the earth's surface are small-scale maps.

Distribution maps are most useful to people working in contaminated areas. The first most useful distribution map is one that shows the distribution of contamination over the mapped area. In addition, distribution maps of vegetation, rainfall, minerals,
soils, etc., may be essential for the successful containment and remediation of the contamination. Sketch maps are drawn free hand and are not usually drawn to scale. They are not accurate representations of the land area but they may be important in locating contaminated sites, or in noting features which are important to the remediation effort, but not shown on any other map. They are often used to illustrate important points in an area.

Map Making
How do you produce a map? The advent of the airplane and the camera have made map making much easier and more accurate. Most maps are based on photographs taken form airplanes or satellites.
The basic tool of the mapmaker is the individual contact aerial-photographic print. These are usually no larger than 24 x 24 cm (10 by 10 inches). Bringing the negative in contact with a sheet of photographic paper and exposing the combination to light makes such a print. The print is then developed as a normal photograph.
If the camera has a 15 cm (6 inch) focal length, the area in the picture will be 186 square kilometers (72 square miles) and will have a scale of 1:60,000. More detail can be obtained by enlarging smaller areas of the negative. Larger areas are obtained by overlapping individual points so that a composite or mosaic picture is obtained.

No matter what type, scale, or area of a map, it must include three crucial pieces of data. That is what part of the earth’s surface is being mapped and how does it relate to other parts of the world. If you were looking for the mapped area how would you find it?
Every map must include a scale. Even if it is only a sketch map it should still contain at least some indication of scale.
Thirdly which way is north. It is very hard to orient the map correctly if the relationship to north is not known.

Soils Maps
Soils maps and maps of contamination are made in just this way. Soil scientist walk the area to be mapped noting different soil types, topographical and other features to be included on the final soils map. Although the notes may be made directly on a photograph, such maps are similar to sketch maps. These notes are then used to make the final aerial map. This data, including the map, is then converted to digital form and stored in the computer. Computer storage allows quick retrieval, correction and updating.

Form remediation efforts it will be necessary to map not only the surface but also subsurface features. Depth to bedrock, water table, depth of contamination, changes in soil type and particularly texture and the direction of movement of water in the soil will all be essential components of the subsurface map. Additional data, specific to the location such as high and low tide water levels along the ocean shore, may also be needed.

Mapping a contaminated site is essential for any remediation plan. However, maps are expensive, and no one map can contain all the data and detail needed for a remediation project. Transparent overlays that contain additional detail can be prepared from acetate sheets. This allows the basic map to be used for a variety of purposes. It also allows two different sets of data to be overlaid on the map at the same time so that features that correspond and those that diverge can be seen.

Information about contaminated water and soil can also be transferred from satellite imagery onto a map. Depending on which imagery you use, it is possible to clearly distinguish clear water in a river, lake or ocean from contaminated or polluted water. It is also possible to identify from a remote sensing soil moisture levels. These can then be mapped and stored in the computer in a Global Information System (GIS).

When carrying out remediation efforts make maps. Both large and small-scale maps will be needed to make an accurate assessment of contamination and potential movement of contamination.
Bio-Treatment of TCE
By Cometabolism

By Jian Xing, Ph.D. and Richard M. Raetz, PE

Trichloroethylene (TCE) is a frequently found organic contaminant impacting groundwater. TCE appears unusable as a primary energy source for biodegradation, but can be destroyed through cometabolism under aerobic conditions. Enzymes (oxygenase) involved in the cometabolic degradation of TCE can be induced by various compounds including methane, ethylene, toluene and phenol.

Oxygenase induced by microorganisms growing on the above substrates fortuitously oxidize TCE to TCE epoxide; which spontaneously degrades chemically to a variety of products that can be mineralized by mixed microbial communities. The oxygenase induced by aerobic microorganisms using phenol is particularly effective for TCE degradation. Therefore phenol was selected as the primary substrate to support bacterial growth in this field application.

Bioremediation describes the process whereby organic wastes are biologically degraded under controlled conditions; preferably to an innocuous state or to levels below concentration limits established by law.

In situ bioremediation has been evaluated as a method of reducing the volume, toxicity, and mobility of on-site contaminants. Biological catalysts used to facilitate this process can include indigenous microbes and/or specially selected microbial inocula.

A pressurized fluidized bed reactor (PFBR) (patent pending) has been successfully used for the treatment of groundwater and process water contaminated by aromatic hydrocarbons. Although cometabolic biodegradation of TCE has been intensively studied recently, and various lab-scale biological systems have reported effective treatment of TCE impacted groundwater, little is known about using PFBR technology for TCE contaminated groundwater treatment in full-scale field applications.

Characteristics of a site in Lansing, Mich. including nature of contaminants, soil type and climate, make it amenable to bioremediation. Hence, in situ and ex situ bioremediation has been integrated with conventional pump and treat technologies to aggressively remove TCE from site soil and groundwater.

The objective of this study was to demonstrate the cometabolic removal efficiency of TCE by phenol-utilizing microorganisms in a full-scale PFBR and in situ biosparging system while integrated with conventional pump and treat/venting technology.

Site Description
The remediation project was conducted in Lansing, Mich. at a site where TCE exist in both soil and groundwater. Investigation efforts revealed that the site TCE impact existed within a complex soil network composed of peat, clay, silty clay, sand with gravel and silty sand lenses varying in thickness from 2.5 to 220 cm.

Each lithologic unit was discontinuous and of extremely low permeability in both the saturated and unsaturated sections of the aquifer. A series of artificial drainage corridors, two meters plus in width, were created for effective aquifer water removal, treatment, and reinjection. The corridors were

Jian Xing and Richard M. Raetz are with Global Remediation Technologies Inc., Traverse City, Mich.

Figure 1: Integrated bioprocessing system
installed below the unsaturated zone, which were approximately four meters to one half meter in thickness. The subject saturated zone terminated at five meters from the top of the unsaturated zone on a base clay layer.

Adsorbed-, pore trapped- and soluble-phase TCE was distributed over 4500 m² with TCE concentrations in soil ranging from 100 to 1,800 ug/kg. TCE concentrations in groundwater ranged from 12 to 440,000 ug/l.

Remedial Process
A simplified mechanical flow diagram of the integrated bioremediation system is shown in Figure 1. Groundwater was recovered from the source area plume, amended with balanced nutrients and oxygen, and passed through the PFBR or air stripper for treatment. Treated effluent from the PFBR containing enrichment cultures was amended with nutrients a second time and injected back into the biosparging window through 15 injection laterals. Air stripper effluent was partially surface water discharged (50%) and partially mixed (50%) with PFBR effluent for reinjection.

Oxygen was added to the biosparging system through a series of passive air sparge wells placed within the reinjection window. The operation of this integrated bioprocessing system was controlled remotely, and in part automatically, by a computer based monitoring and data collection system.

Pressurized Fluidized Bioreactors
The PFBR system consisted of two pressurized fluidized bed reactors. Each reactor column was a 2.4 meter tall by 0.6 meter diameter stainless steel vessel; having a working volume of 700 liters. Each reactor was filled with 200 liters of activated carbon as the biomass attachment media. The unexpanded height of the carbon bed was 0.7 meters.

The two reactors were alternatively fed with a phenol solution (the primary substrate) and TCE impacted groundwater at 12-hour intervals to minimize competitive inhibition while the TCE was being cometabolized. The PFBR feeding rate for TCE contaminated groundwater was 23 L/min creating a HRT of 30 minutes. The PFBR feeding rate for the phenol solution was 11.3 L/min creating an HRT of one hour. Oxygen gas (purity 99%) was supplied to the bioreactor to maintain a dissolved oxygen (DO) effluent concentration of 4.8 mg/L. The PFBR effluent was amended with nitrogen and phosphorus and re-injected into the impacted aquifer after passing through a 35 to 50 micron filter.

Biosparging-Venting System
Passive air sparging was used to provide oxygen to the aerobic bioprocess (biosparging). Oxygen was supplied to the TCE impacted area through sparge laterals 3.2 cm in diameter by 305 cm in length. Air sparge rates were generally 7 standard L/min for each lateral. Vent wells were constructed to create a negative pressure in the aquifer system while the biosparging system operated. Venting rates were approximately 17.5 standard L/min each. Liquid samples were collected in

Continues on page 38 →

![Figure 2: TCE removal efficiency vs. influent TCE concentration.](image)

![Figure 3: TCE recovery capacity vs. influent TCE concentration.](image)
40 ml glass vials on a weekly to monthly basis. Quantitative analysis of liquid phase TCE and phenol was performed using gas chromatographic (GC) analysis. EPA Methods 8010 (TCE) and 604 (Phenol) were employed.

**PFBR Start Up**

The PFBR was initiated with mixed inoculum containing a known capacity to degrade TCE obtained from a batch reactor, and activated sludge from a local wastewater treatment plant. Nitrogen (N) and phosphorus (P) were added to the influent at a stoichiometric ratio of 100/5/1: COD/N/P.

Micro-organisms capable of cometabolizing TCE were cultured in the PFBR at a HRT of one hour and organic loading rate of 3 kg COD/m²-day. After eight weeks of reactor operation, the biomass concentration reached 20 g/L (as suspended solids) and the reactor achieved a 95% phenol removal efficiency.

When biomass was fully developed in each PFBR, TCE contaminated groundwater and stock phenol solution were alternatively fed into each PFBR in 12 hour intervals. The periodic shift of the PFBR feeding conditions was performed by using timer controlled solenoid valves.

Lab test results revealed that the phenol utilizing microorganisms, cultured in the PFBR reactors, could degrade TCE at a maximum degradation rate of 80 mg TCE/g-SS-day. During the field operational period, the influent TCE concentration fluctuated from 700 ug/L to 50,000 ug/L with an average value of 15,000 ug/L.

The corresponding TCE loading rate of the PFBRs varied from 0.1 to 1.9 kg/m²-d. Based on operational data, the PFBR reactor continuously removed TCE at an influent TCE concentration up to 50 mg/L and a HRT of 30 minutes.

The TCE removal efficiency varied with influent TCE concentrations and ranged from 31-68%. It appears that the TCE removal efficiency increased with an influent TCE concentration increase from 2 mg/L to about 25 mg/L. Beyond this range, the TCE removal efficiency began to decrease as the influent TCE concentration increased. This observation is consistent with laboratory controlled experimental results (Figure 2).

The observed TCE removal capacity of the PFBR is presented in Figure 3. As shown in this figure, at an influent TCE concentration of 33 mg/L a maximum TCE removal capacity of 0.89 kg/m³-d was achieved. This field operations data also compared favorably with lab test results. During the field operational period the average effluent DO concentration was 4.8 mg/L, while the average pH was 7.6.

**Overall Site Results**

The fully integrated bioprocessing system started operation in May of 1997. Due to the effective operation of the integrated system, the TCE concentration in the source area decreased continuously (Figure 4).

The PFBRs, while treating source area water, generated microorganisms capable of degrading TCE cometabolically. These microorganisms were injected into the subsurface zone of TCE impact. Injected microorganism populations were 1.1 x 10⁶ CFU/ml (as quantified by the substrate phenol).

After seven months of this continuous enrichment culture addition, the in situ microorganism population increased from a low of 3.10x10⁵ CFU/ml to 5.04 x 10⁶ CFU/ml (as quantified by the substrate phenol).

Based on field operational data, 131 kg TCE has been removed from the subsurface zone of TCE impact within 15 months. Over the course of treatment, the aquifer temperature varied from 9.2°C to 19.8°C with an average value of 14.8°C. The aquifer pH slightly fluctuated around 7.7.

This study demonstrates the effectiveness and advantage of using integrated biological processes for industrial sites impacted with TCE. The PFBR system can be used both as a ex situ TCE treatment process and "most importantly" an inocula source for enhanced in situ bioremediation. As demonstrated by the operational results, integrating PFBR technologies with biosparging, air venting and conventional pump and treat technology has produced the effective removal of 131 kg of soluble phase TCE from the aquifer system within 15 months.
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As an attendee at the 1999 Environmental Technology Expo you'll also have free crossover privileges to three adjoining shows: the OSHA Compliance Expo, the Plant & Facilities Expo, GeoExchange Expo, and the 22nd WEEC.

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Soil & Groundwater August/September 1999
September 14-15, 1999
ASTM Phase II Environmental Site Assessment Course. New York, N.Y. Eileen Finn 610-832-9686.

September 14-15, 1999

September 16-17, 1999

September 20-23, 1999

September 21-22, 1999

September 21-22, 1999
In-situ Permeable Reactive Barriers: Application and Deployment Training Course. Philadelphia Marriott Hotel. Contact Cloyce Brackett or Kimberly Sams at SSEB 770-242-7712.

September 21-22, 1999
ASTM Training Course on Risk-Based Corrective Action for Chemical Releases. West Conshohocken, Penn. Contact Eileen Finn 610-832-9686.

September 21-24, 1999

September 22-24, 1999

September 28-29, 1999

September 28-29, 1999

September 30, 1999

October 3-7, 1999

October 4-7, 1999

October 5-6, 1999
ASTM Phase II Environmental Site Assessment Course. Dallas. Contact Eileen Finn 610-832-9686.

October 5-7, 1999
Trimble 5th Annual User Conference and Exhibition on the application of GPS. San Jose, Calif., Convention Center. Info contact Conference Coordinator 408-481-8465.

October 5-7, 1999

October 5-7, 1999
Georgia Tech Sustainable Real Estate Development. Atlanta, Paul Weber Space and Technology Building on campus. Call 404-894-2401.

October 6-7, 1999

October 7-8, 1999

October 12-13, 1999

October 15, 1999
Following is the planned editorial calendar for the coming year. These are the areas of emphasis for upcoming issues. Our regular columns will also appear, along with a few new columns of interest to the industry. Of course, we will offer feature articles throughout the year on subjects that impact the industry, but fall outside these broad categories.

**February/March** issue will be our annual issue dealing with Bioremediation. We are also planning a Guide to Graduate Courses through internet programs.

**August/September** will be our annual Product Directory (Buyer's Guide) along with a new Consultant Directory. Also in this issue will be Wetlands Remediation.

**April/May** will be our annual State by State Water Standards issue. Also featured will be articles on the National Labs and on Metals.

**October/November** will feature our reader favorite, Innovative Technologies. Additional editorial spotlight will be on Heavy Equipment.

**June/July** will deal with Sediments Remediation and Risk Assessment. Additionally this issue will feature a Software Directory.

**December/January** will bring us around again to our State by State Soil Standards issue. Also featured in this issue will be Containment Technology.

We actively seek article contributions from industry participants. If you have a concept, e-mail a very brief description to: twcombs@sgcleanup.com. Be sure to make reference to the issue to which you hope to contribute. We'll work with you by providing editorial guidelines, and by providing personal help, if needed, in putting your article together for publication.
The Association for the Environmental Health of Soils (AEHS) was created to facilitate communication and foster cooperation among professionals concerned with the challenge of soil protection and cleanup.

Experience over the past decades has revealed the need for a consistent and reliable network for the exchange of information derived from multiple sources and disciplines among people who, because of different disciplinary affiliations and interests, may not have easy access to significant portions of the information map.

AEHS provides the network. AEHS members represent the many disciplines involved in making decisions and solving problems affecting soils, including chemistry, geology, hydrogeology, law, engineering, modeling, toxicology, regulatory science, public health, and public policy.

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TPH Soil Test Kit

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In February, 1999 Current Environmental Solutions (CES), Mission Viejo, Calif., was retained to remediate Tetrachloroethylene (PCE) from beneath a former dry cleaning business. The dry cleaners was located in the corner storefront of a retail mall in western Washington state. While empty for remediation, the storefront shared common walls with two other active retail businesses (site map).

The site owner required rapid remediation to support a fast track property transfer. CES used their Six-Phase Heating™ (SPH) to remediate the site soil and groundwater to Washington State MTCA Method A cleanup criteria.

Prior to initiating remediation, the local consulting firm performing the site characterization discovered that the PCE plume extended beyond the footprint of the dry cleaners and into the adjacent alley. Remediation efforts were immediately expanded to simultaneously treat both the interior and exterior segments of the plume.

Site lithology consisted of sands to sandy-silts and an extremely shallow groundwater table was encountered at 2-4 ft below grade. Initial PCE concentrations were 2,000 µg/kg in soil and 3,600 µg/L in groundwater. PCE cleanup goals were 500 µg/kg in soils (75% removal) and 5 µg/L in groundwater (99.9% removal).

Teaming with a local remediation firm, CES constructed 15 SPH electrodes inside the former dry cleaning store and 12 electrodes in the alley. Electrodes extended to a depth of 20 ft below grade, and were electrically conductive from 12-20 feet below grade. These electrodes heated the subsurface from 2-22 ft below grade. Inside the building, CES installed the SPH system through the concrete floor slab. Performing SPH in the alley however, represented a challenge. The alley contained buried utilities for sewer, electrical, water and natural gas. Additionally, it was a fire lane and could not be closed. CES developed a unique electrode design and installation process that allowed the alley to remain open to delivery truck and pedestrian traffic throughout SPH operations.

The subsurface was heated by a 500kW power supply. Steam created by heating was collected in four horizontal soil vapor extraction wells, two inside the building and two in the alley. Condensation was discharged directly to the sanitary sewer while vapors were treated by activated carbon.

With less than 90 days of operations, remediation was complete. PCE levels in groundwater were non-detect beneath the building and have been reduced well below cleanup criteria in the alley. Average PCE concentrations were reduced by 99.7%. Remediation goals were met within the strict time constraints required for an expedited property transfer.
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Soil & Groundwater August/September 1999 45
The Association for the Environmental Health of Soils (AEHS) and The Naval Facilities Engineering Service Center invite you to exhibit at the Tenth Annual West Coast Conference on Contaminated Soils and Water. For the past nine years, this annual conference has helped to bring together the environmental science community by providing a forum for the exchange of information.

Attracting over 400 participants in 1999, the West Coast Conference is a highly successful and nationally known conference focusing on important and timely environmental issues related to soil and water contamination. Attendees are drawn from a variety of professions including state and federal regulatory agencies, the petroleum and chemical industries, transportation and utilities, environmental engineering and consulting firms and academia.

The exhibit area is located in the center of the conference activity to assure maximum contact and exposure with interested conference participants and potential customers. Exhibition space is limited to 22 booths to insure a high ratio of attendees to exhibitors. The rental fee for exhibit booth space is $750.00. This fee covers:

- 8' x 10' exhibit booth space
- 1 - 6' skirted table
- folding chairs
- wastebasket
- electrical power outlet
- promotion of your company name in conference flyers and programs
- list of conference attendees (hard copy or diskette)
- exhibitor staff badges (4 per booth)
- one complimentary conference registration.

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Sediments
Water sessions
Wetland Restoration

Abstracts for poster presentations are invited for consideration on any of the above topics.

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