Consultants share their top three concerns

page 6
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Write in 056
When we asked contractors and consultants for their opinions about the most critical issues in the contaminated soil and groundwater industry today, we halfway expected to come up with a definitive list of three single issues that most everyone would agree on. Pretty naive, don’t you think? Instead, the issues that concern the contractor/consultant vary from company to company and from individual to individual. A roundup of some professional’s opinions as to their “Big 3” appears on pages 6-7.

The group didn’t agree wholeheartedly on anything. In regard to whether this industry is currently growing, stagnant or regressing, 42 percent of respondents feels the industry is regressing; 33 percent (largely the respondents from larger companies) sees growth in the industry; the remaining 25 percent sees neither growth nor regression.

Are trade organizations responding to the needs of industry professionals? Yes, says 38 percent of respondents. And governmental entities? They are doing about as well as trade organizations. About 36 percent say they are responding to the industry in positive, constructive ways.

And how has the industry fared in terms of innovations? The list is lengthy. Among the nominations for the most innovative advances this year: reactive walls to control off-site flow of chlorinated organics; the LLNL report on leaking USTs; RBCA; efforts to deal with DNAPLs; indirect thermal desorption; and an increase in the range of options available to remediate sites and the increase in the use of these options.

Other innovations mentioned include the emergence of phytoremediation, in situ thermal desorption, advances in computer hardware and software and various in situ treatments.

Some of our contractors/consultants left this question open, not seeing innovations occur this year. A report coming out in October agrees that the market for innovative technology is hindered and calls for changes that must occur to open this market up. See a preview of this report on page 19.

Do you know of a worthy innovation? Share it with us. We are featuring this year’s innovative technologies and advances in an upcoming issue.

Jody Becker
Managing Editor
August/September 1997

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Abbreviations and acronyms:
AST - above-ground storage tank
BTEX - benzene, toluene, ethylbenzene and xylenes
CERCLA - Comprehensive Environmental Response, Compensation and Liability Act
EPA - U.S. Environmental Protection Agency
ppb - parts per billion
ppm - parts per million
psi - pounds per square inch
RCRA - Resource Conservation and Recovery Act
UST - underground storage tank
VOC - volatile organic compound

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page 45
The subsurface contamination industry comprise myriad ideas, concerns and issues. Each facet of the industry brings its own unique perspective to the table. Soil & Groundwater Cleanup asked consultants and contractors to share the three issues that they believe are at the forefront of the industry today. What follows is their input.

Steven M. Gamelsky, P.E., Principal
GEA Engineering, P.C.

1. The need to establish nationwide categorical, itered cleanup levels for soil and groundwater that are achievable with current technology, reasonable in cost and protective of the environment. Owners need to know that spending money on cleanups can achieve the desired results. Cleanup standards should be consistent and realistic. The move towards risk-based cleanup levels is a step in the right direction. But the RBCA analysis is unnecessarily complex and the equation variables can be manipulated. For petroleum contaminated sites, for example, there could be four tiers of cleanup standards for soil and groundwater ranging from high risk to low risk or insignificant impact. This approach would be applicable for 99 percent of the sites.

2. The need to revise liability standards for Brownfield and contaminated sites. Revisions to CERCLA liability provisions and State regulations is needed to pursue aggressive cleanup and reuse of industrial Brownfield sites.

3. The non-regulation of small (<4165 liter) USTs. There is a huge inventory of single-wall steel USTs that is unregulated and that are contributing to environmental degradation. Most of these are in the residential sector.

Jeffrey Paul, President
Golder Applied Technologies

1. Chlorinated solvent removal without impacting existing operations.
2. Risk-based Corrective Action.
3. Reuse of impacted land.
Why are these issues important?
- The need for owners to continue operating their facilities during remediation activities so that these operations may continue to generate revenue.
- The need to manage risk.

Richard A. Sager, P.E. and Principal Engineer
Hargis + Associates Inc.

1. Shrinking market for environmental services.
2. Too many consultants and contractors chasing fewer opportunities.
3. Low price competition vs. quality of services.
Why are these issues important?
- Future survival or positioning in the environmental marketplace.
- Maintaining existing client relationships.
- Specialization and development of market niches based on areas of expertise.
- Developing new marketing opportunities.
Christine Cesaria, Marketing/Information Manager
P.W. Grosser

1. Changing regulations.
2. Cost/profit.
3. Time/rate of cleanup.
   Why are these issues important?
   Because they can mean the difference between doing an accurate, compliant job on time or a slow-moving, unprofitable job.

George e. Boyajian, Ph.D., CEO
PhytoWorks Inc.

1. Survival
2. Survival
3. Survival. With the high degree of competition and the limited number of contracts available, companies have gone so far as to submit bids below their costs with the hopes of outlasting their competitors. Those who will ultimately survive and sustain long-term profitability are those who proactively turn to more cost-effective, innovative technologies. Many companies are doing just that.

Jim Percell, President
OnSite Technology LLC

1. Enforcement of existing regulations.
2. Modifications to existing regulations which may have negative impact on industry revenues.
3. Acceptance of natural attenuation.
   Why are these issues important?
   Environmental cleanup of contaminated soil and groundwater is driven by regulations. Without them, the industry resources would be severely reduced. Those polluters who have environmental consciences are few. The enforcement will create revenue for the industry. Obviously, modification to lessen environmental cleanup will have a negative impact on an already stagnant climate. As natural attenuation is further accepted by regulation this will also create further downward pressure on revenues and the long range stability of the industry.

Randall McAllister, Geosciences Dept. Manager
Roy F. Weston Inc.

1. “How clean is clean?”
2. Variable goals site by site and state by state.
3. Lack of technologies which can address recalcitrant compounds.
   Each of these issues create situations whereby solutions are perceived not as solutions but as “band-aids.” In many cases, this perception is reality.

Sirous H. Djafari, Ph.D., P.E.
Vice President & Technical Director
IT Corp., Pittsburgh

1. Cleaning sites with dense nonaqueous phase liquids (DNAPLs).
2. Dealing with mixed wastes.
3. Determining environmentally acceptable soil and groundwater cleanup levels.
   Why are these issues important?
   To be able to solve numerous outstanding issues related with site closure and cleanup.

Gary R. Brown, P.E.,
President RT Env. Services

1. Unrealistic standards.
2. Unrealistic client expectations.
3. Owners wanting to shift liability. Why are these issues important?
   They affect the ability to complete a project effectively and within budget.
December 2nd-4th, 1997 Sheraton Washington Hotel Washington, DC

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The Brownfields Initiative:  
Program is designed to improve the economics of environmental restoration

By William Duvel, Ph.D., P.E.

Brownfields sites — abandoned or underused industrial or commercial property — have been shunned by most commercial and industrial developers for more than 15 years. Developing Brownfields properties is significantly complicated by legal liability and environmental contamination — both real and perceived.

Thus, the trend with industrial property use or reuse has been to avoid potential economic loss associated with remediating urban industrial sites, and move redevelopment and new industry to pristine undeveloped sites or greenfields outside cities.

EPA’s Brownfields Initiative attempts to reverse this trend by encouraging redevelopment of underused industrial and commercial property in urban areas by reducing the fear of future cleanup liability. With the Brownfields Initiative, EPA has recognized the obstacles to urban redevelopment and efficient environmental cleanup must be removed to promote growth in cities and reuse of overlooked industrial properties.

The initiative provides incentives and economic rewards to owners and developers of Brownfields properties. By encouraging such redevelopment, the Brownfields Initiative strengthens urban communities by increasing jobs and enhancing the tax base, and will re-emphasize the historical industrial base.

Due to the poor economic prospects, Brownfields sites are complex projects with multiple risks that must be carefully evaluated. While Brownfields redevelopment offers significant business and civic advantages, effective Brownfields site redevelopment requires the cooperation, skills, resources, commitments and vision of many stakeholders, including property owners; federal, state and local officials; lenders and financial institutions; property developers; civic and community organizations; environmental and remediation consultants to resolve the many issues associated with these sites. Some of these issues include zoning restrictions and land use considerations, tax exempt bond issues or low interest financing, as well as the many requisite due diligence, environmental assessments and impact studies before cleanup.

To achieve its industrial redevelopment objectives, EPA has promoted the Brownfields Initiative with an action agenda. This agenda includes encouraging state voluntary cleanup programs, reassuring owners of properties situated above contaminated aquifers, approving prospective purchaser agreements, developing cleanup guidance, and removing 25,000 sites from the CERCLIS Superfund tracking system list. The removal of these least contaminated sites from the Superfund program and its associated rigorous cleanup requirements goes a long way toward removing the fear of legal liability that has tainted these sites. Additionally, the EPA is funding 72 pilot programs at up to $200,000 each to support creative demonstration of redevelopment solutions.

EPA encourages voluntary cleanups

For many industrial companies, one of the most important elements of the Brownfields Initiative is its emphasis on state control of voluntary cleanup programs. Generally, the Brownfields Initiative does not provide a new avenue for cleaning up sites. Cleanups will still occur under federal guidelines or state equivalents, underground storage tank programs, or state voluntary cleanup programs. However, the Brownfields Initiative encourages:

• Cooperation between the property owners and the state regulators through state voluntary cleanup programs.
• Creative risk-based solutions that foster redevelopment and reuse of property based on planned land use, and;
• Rapid turnaround in remediation and redevelopment of properties.

In one recent remediation example, ENSR successfully cleaned up a contaminated industrial site under the Colorado Voluntary Cleanup Act which produced excellent savings and an expedited schedule for the property owners. In this case, within 9 to 12 months of agreeing on the voluntary cleanup approach, cleanup was completed and regulatory compliance achieved while still protecting the public health.

William Duvel, Ph.D., P.E. is a vice president at ENSR, Acton, Mass. Dr. Duvel heads ENSR’s KEERA/Brownfields business nationwide.

Continues on page 10 →
To realize these objectives, risk assessment, fate-and-transport modeling, and natural degradation were used as part of its creative site-specific remediation solution. State agency regulators were very pleased at the comprehensive approach and remedial risk-based solution designed and implemented for the site. The Colorado state agency issued a no-further-action letter, the property was sold and has been redeveloped for other uses. What was a defunct operation is now a beehive of activity.

Proof of the success of this cleanup is in the numbers. Total cost for the facility cleanup was about $350,000 and the property is already under redevelopment as a manufacturing facility. Under strict RCRA or CERCLA, cleanup requirements, facility cleanup costs would likely have exceeded $1 million and taken several years to achieve.

A growing number of states are adopting such voluntary approaches.

Brownfields Initiative leads to new economic efficiency

Traditionally, the costs of site remediation have been largely dictated through EPA's regulation of industry. Stringent cleanup standards and objectives -- the most important factors in determining how much site remediation will cost -- set by the regulatory community can often be difficult, if not impossible, to achieve at many sites. The principal of diminishing returns also applies during hazardous waste site cleanups. As cleanup costs rise rapidly to meet upper-limit cleanup or treatment standards, the benefits of such cleanup levels decline.

Thus industry and regulators debate whether the costs to achieve the regulators' overly stringent standards is too high. The Brownfields Initiative is EPA's attempt to bridge the gap between industry and EPA that stalls or impedes cleanups and redevelopment. The ultimate product of the initiative may be a new level of economic efficiency where cost effective/risk protective solutions can be achieved.

Innovation reduces cleanup time

A voluntary cleanup at a site in Illinois in 1989 exemplifies cost-effective risk based environmental solutions now being promoted through the Brownfields Initiative. Work at this site resulted in substantial economic benefit to both the former owner of the property, the developer, the new owners of the property, and the surrounding community.

In addition, the voluntary program allowed for an approach that produced an innovative remedial technology for removing dense non-aqueous phase liquid (DNAPL) chlorinated solvents from soil and ground-water. This technology reduced the remediation time from an estimated 30 years to about four years.

At this site, more than 11,349 kg of solvents were removed from the subsurface. The success of this remediation was accomplished at a remediation cost savings of more than $50 million at a site located over an aquifer and with the presence of extensive DNAPL, a pervasive contamination problem that often results in long remediation time frames and high remediation costs.

Because agency regulators encouraged the use of innovative approaches under the Illinois voluntary cleanup program, a solution was developed that solved the problem much faster and at a much lower cost. In addition, 95 percent of the property was redeveloped into a shopping mall during the implementation of the remediation system. This cleanup enabled the conversion of a closed manufacturing plant into a community shopping center which now provides additional beneficial resources and jobs to the community.

Through Brownfields, EPA is moving away from the concept of pristine cleanup to more risk-protective/cost-effective approaches. It also addresses other economic problems and disincentives presented by hazardous waste regulatory programs. Through these efforts, industrial companies can hope to achieve quicker and more cost-effective solutions to environmental problems.

The Brownfields Initiative and Voluntary Cleanup Programs are designed to bring together regulators, developers, lenders, property owners, civic leaders, and citizens to put severely impacted land back into productive use. This new push for redevelopment is helping create a more positive atmosphere for site cleanup, providing improved communications in the community, and resulting in strong economic benefit for all involved in the program.

The Brownfields Initiative and Voluntary Cleanup programs as promoted by EPA will bring more certainty to the liability issues present under current regulations. The issues of CERCLA liability, and how clean is clean, and the future use of property will become more clear.
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Brownfields-Special Session
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- Closing the Deal: How Deal Structure Can Affect Risk and Liability and Your Ability to Close
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- The State of the Art: New Brownfields Products
- The Shift for CERCLA to Brownfields: A Case Study in Illinois

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The annual Contaminated Soils Conference at the University of Massachusetts at Amherst has become the preeminent technical national conference in this important environmental area. The conference attracts 700-800 attendees annually which includes a wide variety of representation from state and federal agencies; military; industries including, railroad, petroleum, transportation, utilities; the environmental engineering and consulting community; and academia. The conference will be supported by the development of a strong and diverse technical program in concert with a variety of educational opportunities available to attendees.

The exhibition section brings real-world application to the technical theory and case studies which will be presented in the platform and poster sessions. Focused workshops will provide attendees with the type of practical application information which will impact their job performance immediately.

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The conference promises to be an exciting opportunity for all those concerned with the challenge of developing creative cost-effective assessments and solutions that can withstand the demands of regulatory requirements.

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Implementing risk management at manufactured gas plant sites

By Charles A. Menzie

In the past decade, much has been learned about the characteristics of Manufactured Gas Plant (MGP) sites, the health and ecological risks they pose, and methods for addressing these risks. Remediation of these sites has spanned a broad spectrum of technologies ranging from containment to sophisticated treatment of soil and groundwater. To a large extent, this was a period of learning how to implement risk management strategies at these sites.

This learning experience at MGP sites — with its successes and failures — is paralleled by similar experience at contaminated sites in general. Thus, evolving risk-management approaches can be for petroleum hydrocarbons, PCBs, metals and many other classes of soil contaminants at specific sites or regions.

While we have learned much about specific issues at MGP sites, we have also learned about risk management approaches for soil contamination. The emergence of risk management as an organizing framework for addressing soil contamination issues is perhaps the most critical development over the past decade. Approaches for addressing contamination at MGP sites can be best understood within this larger context.

Emergence of risk management

Risk assessment by itself is an orphan. A request — often heard from industrial clients or regulatory agencies — to “go do a risk assessment” is incomplete if it is separated from the overall risk management context. Risk assessment is a tool, not an end in itself. To understand how, or even when, to use risk assessment, the risk management context must be identified and the questions or information needs clearly defined.

While this may appear obvious, there are many risk assessors and risk managers that fail to have the interactions necessary to develop and implement effective risk management approaches. To some degree this reflects historical misconceptions concerning the roles of risk assessment and risk management.

There are a number of examples of emerging risk management approaches for soil contamination problems. The first publication of the GRI Volume III report for MGP sites in 1987 — since updated — is one of the first to outline an integrated approach for site investigation, risk assessment and site remediation. (See Figure 1, page 14).

The risk assessment components were tiered; screening-level assessments led toward more sophisticated approaches depending on the information needs of the risk-management decisions. This integrated risk-management approach became widely used by industry and regulatory agencies for MGP and other sites.

A similar concept is embodied in the ASTM (1995) Risk Based Corrective Action (RBCA) for petroleum release sites. (See figure 2, page 16) RBCA involves a tiered assessment strategy wherein risk-related information, decisions, and remedial options are considered in a sequential manner. ASTM is currently working on a RBCA approach that can be applied to all sites.

RBCA promises to be a useful and understandable way to organize and interrelate risk management components for addressing contaminated soils. As a result, various organizations, groups, and agencies are using RBCA to help fashion their approaches.

For example, the Total Petroleum Hydrocarbon (TPH) Criterium Group has adopted the RBCA strategy. Further, a number of states have also moved toward risk-management approaches that use tiered strategies and which clearly link risk assessment activities to specific risk-based questions and remedial options. RBCA has served as an organizing framework for many of these states.

The 1994 to 1999 period will mark the emergence of risk management approaches to site assessment. This means more than simply using the results of risk assessments to guide decision making. There are a number of factors and stakeholder issues that may enter into risk management decisions. Further, there will be an increasing emphasis on the goals of the risk management effort and on providing solutions to environmental risk reduction.

Risk assessment methods have continued to develop over the past decade as we have thought more about how to characterize exposure, effects, risk, and uncertainties in...
these estimates. As a result, risk assessment techniques range from simple screening-level methods to sophisticated two-dimensional Monte Carlo analyses.

Accompanying this range of methods has been a debate about the correct way to conduct risk assessments. This debate has often pitted risk assessors working for regulatory agencies, consulting companies, and industry against one another. This is unfortunate and has often led to frustration on all sides. From a risk management perspective, it should be clear that any of the methods might be appropriate depending on the information needs of the decisions.

The ability of the parties to communicate with one another and with other stakeholders about the approach is also a critical consideration in the selection of appropriate methods. The methods chosen should yield results that can be effectively used in a decision-making framework. Risk communication plays a significant role in risk management decisions.

These elements underscore the value of tiered assessment strategies that link risk assessment methods to decisions and that progress from simple to more sophisticated analyses. Successful decisions — short of litigation — are most likely to come about when all sides have a clear understanding and acceptance of the assessment process and how it will be used within the decision making framework.

Major risk management issues at MGP sites

Many MGP sites are located in urban environments where contamination exists due to non-site related sources. Even in rural areas, activities can give rise to local conditions where contaminants are elevated in soils surrounding a site. How should such local conditions be taken into account within the risk management process? Is it possible to differentiate between the site and general conditions present in the region?

The issue of how to account for local conditions is multifaceted and can cause frustration on all sides. Most often, the issue arises at MGP sites with respect to polycyclic aromatic hydrocarbons (PAHs), a class of chemicals present in coal tars that usually drives risks at these sites. The issue of local conditions has also arisen for lead at some sites.

PAHs and other contaminants such as lead can be present in urban and some rural areas as a result of other anthropogenic and natural sources. Concentrations of PAH and lead in soils associated with local conditions can exceed risk-based screening levels and calculated risk thresholds. This phenomenon clouds risk management decisions with respect to the site and how it should be differentiated from surrounding areas.

The issue can be addressed, in part, by a process that recognizes that chemicals can be present due to off-site sources. The site can then be evaluated within the context of local conditions. There are a range of risk management considerations such as risk reduction objectives, liability, and feasibility that should be part of this evaluation.

Regional data collection efforts can be helpful in placing the results obtained at a site into perspective. In some cases, studies directed at establishing local background conditions can be especially beneficial.

Unfortunately, because the collection of off-site data is often seen as a cost that is not yielding site-specific information, there is a tendency to perform such studies poorly in an effort to save money. This can limit the value of the assessment and result in misleading characterizations. As a general rule, a sound statistically-based sampling design is an important starting point for establishing local or regional conditions.

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Write in 414
MGP, from page 13

An individual’s perspective on local conditions and acceptable concentrations levels for soils is affected by a wide range of factors. These include an individual’s perception of risk, the reliance placed on numbers, their familiarity with the physical and chemical properties of the contaminants, the role that the individual has in the risk management process, and the breadth of their risk management experience. In such cases, constructive and frequent communication is needed to develop a common base of understanding on all sides of the issue.

Surprisingly, risk assessors whose experience is limited to the conduct of risk assessments, may have little risk management experience and a poor understanding of the needs of the risk manager. They can become focused on the process, in particular on the sets of equations that yield risk estimates and target levels. While these risk estimates and target level values are important and valuable for risk management, a strict calculation-based approach can preclude consideration of other factors.

This can be called risk assessment myopia, a phenomenon that can lead to outcomes that challenge common sense. Examples include the derivation and reliance upon target levels well below ambient levels — soil concentrations in the low parts per billion for some PAH compounds — as well as values at which soils would be almost saturated with a chemical — many non-carcinogenic organic chemicals such as xylene and toluene and inorganic compounds. Such outcomes should be a flag that other factors should be considered within the risk management framework. Local conditions is one of these factors.

Understanding and using information on exposure

Many of the decisions regarding assessment and remediation at MGP sites are based on exposure issues. Exposure distinguishes sites from one another, governs risk estimates and can be effectively reduced through a number of remedial options. In cases where treatment alternatives designed to reduce toxicity are unavailable or infeasible, remedial alternatives that reduce or eliminate exposure offer the most promising opportunities for risk reduction.

Assessing exposure associated with soils and wastes at MGP sites typically involve understanding:

- vertical and horizontal distribution of chemicals;
• concentrations of chemicals;
• bioavailability of the chemicals;
• ability of chemicals to migrate in gaseous, aqueous, non-aqueous phases or solid form;
• current and planned uses of the site and how people and ecological receptors might be exposed via these uses;
• other pathways by which people or ecological receptors might be exposed to chemicals at the site.

These are elements of a site conceptual model. The large knowledge base on the exposure characteristics of chemical contamination at MGP sites has made it possible to develop risk management guidance for these sites. However, sites can differ and planned uses for such sites may also differ.

Site-specific conditions and land use plans provide opportunities for creative and effective approaches for reducing risks and restoring land to a practical use. MGP site managers around the country are seeking solutions that involve eliminating exposure pathways at sites so that the site can be used for industrial or commercial use or even as recreational areas.

The value of creative solution-oriented approaches to restoring urban properties is becoming increasingly recognized. The concept has received much attention within Brownfields initiatives and some MGP sites are being redeveloped in this context. Some utilities have entered into consent orders to evaluate and remediate sites to industrial land use. Others have proceeded with assessments and restorations projects consistent with state policies that allow for consideration of land use.

Restoration and risk reduction projects that rely upon eliminating or minimizing exposure pathways require knowledge concerning how exposures occur, the ability of chemicals to move through barriers, and methods that effectively eliminate sources or prevent migration from sources to locations where exposure could occur.

Approaches may involve the removal of hot spots at or near the soil surface combined with various containment or barrier methods including the footprint of buildings, capping with paving and subsurface venting.

The ability to implement risk management solutions that involve controlling or eliminating exposure is dependent on state regulations. Some states — often those with many urban sites — are making an effort to develop flexible approaches for site restoration. Other have adopted more conservative approaches that explicitly or implicitly incorporate a no degradation policy.

These positions reflect different points along a risk management spectrum. They are not necessarily inconsistent. Frequent and constructive communication among the stakeholders is especially important when alternative solutions are sought. In some cases, legislation may need to be modified to allow for creative alternative approaches to be employed by the agencies.

Understanding and using information on effects

Risk management decisions at MGP sites are most often driven by the presence of coal tar either as a non-aqueous phase or mixed with soil or other media. Coal tars are complex and variable mixtures of hydrocarbons. There is limited information on the toxicity of these mixtures.

Most risk assessments have evaluated effects by relying on the limited information available for priority pollutant compounds associated with the tars, primarily PAHs. As a result, there is large uncertainty associated with evaluating the effects of these compounds. Other chemicals that have driven decisions at sites include volatile organic hydrocarbons such as benzene in atmosphere and groundwater, iron cyanide compounds and occasionally metals.

Continues on page 16 →
Initial Site Assessment (6.2.1)
Conduct site investigation and summarize available site information regarding chemical(s) of concern, extent of affected environmental media, and potential migration pathways and receptors.

Site Classification and Initial Response (6.3)
Classify site based on the need for initial response actions. Implement initial response actions. Reclassify site, as appropriate, following Initial Response Actions, Interim Remedial Actions, or additional data collection.

Tier 1 Evaluation (6.5)
Identify reasonable potential sources, transport pathways, and exposure pathways (use flow chart given in Figure 1). Select appropriate Tier 1 risk-based screening levels (RBSSL) from the Tier 1 "Look-up Table," or other relevant criteria (e.g., aesthetic). Compare these values with site conditions.

Interim Remedial Action (6.7.1.1)
Conduct partial source removal or other actions to reduce the risk(s) and to reclassify the site.

Remedial Action Program (6.10)
Identify cost-effective means of achieving final corrective action goals, including combinations of remediation, natural attenuation, and institutional controls. Implement the preferred alternative.

No Further Action (6.12)

Compliance Monitoring (6.11)
Conduct monitoring program as needed to confirm that corrective action goals are satisfied.
such as lead and arsenic.

The Electric Power Research Institute (EPRI) has taken the initiative to reduce the uncertainty associated with evaluating the toxic effects of coal tars and constituents within this waste material. This program will improve our understanding of the adverse health effects of complex mixtures of coal tars and will improve the predictive ability of assessing the risks to mammals. The EPRI project is also evaluating the effects of the coal matrix in reducing the bioavailability of coal tar constituents. The primary study is now complete and data are being evaluated.

The presence of iron cyanides at MGP sites has caused concern because of the specter associated with the word cyanide. For example, simple cyanide salts are well known acute poisons and can be lethally toxic to people following short-term exposure to relatively high concentrations. This toxicity is associated with the physiological release of hydrogen cyanide. The iron cyanides present at MGP sites do not readily form or release hydrogen cyanide and are considered to have little or not toxicity.

While most scientists within regulatory agencies, consulting companies, and the industry now recognize the large differences in toxicity among cyanide compounds, concern still remains that some exposure conditions might result in releases of small amounts of toxic cyanide. As a result, there have been several efforts under way to characterize these kinetics. Such releases are expected to be small if not negligible. Chemical analytical methods have been explored for deriving conservative estimates of cyanide exposure for selected exposure routes, for example incidental ingestion of the waste materials.

Iron cyanides can cause visible blue staining of materials, an aesthetic impact that can serve as a reminder that cyanide is present and affect the perception of risk. This is a risk management issue in some parts of the country where sites are being redeveloped.

Ecological issues

Ecological issues are being evaluated with increasing frequency at sites throughout the country. In the past five years there has been a concerted effort by state and federal agencies to develop guidance on conducting ecological assessments and using the results in decision making.

At MGP sites, the conduct of ecological assessments has usually been driven by issues related to releases of coal tars to surface water bodies and resultant sediment contamination. Because many MGP

Continues on page 18→

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sites were located on lakes, coastal harbors, and rivers, some facilities have experienced such releases. The problem — when and if it arises — can be highly visible, persistent, and can cause concern for the health of aquatic biota.

The general issue of sediment contamination has taken center stage in the evaluation of aquatic ecological risks by the U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, and many state agencies. Increased attention on this matter can, therefore, be expected. Guidance on how to conduct these assessments for hydrocarbons and other contaminants is being developed. The greatest risk management challenge is how to remediate these conditions.

In contrast to aquatic ecological risks, terrestrial ecological risks have not been a predominant issue. This is due, in part, to the locations of most sites within towns and cities where terrestrial habitats for wildlife are small and fragmented. In such locations, human health risks are typically judged to be more important from a risk management perspective.

Setting priorities

Some utilities may have a number of MGP sites along with other environmental problems. Tackling all of these possible areas simultaneously can be an overwhelming task from a technical as well as a business perspective. It is also evident from experience that sites vary in the degree of risk they pose in the short and long term. They also differ with regard to a host of other factors that may bear on risk management decisions.

Thus, some utilities are using comparative risk management approaches to help prioritize their sites. These have included formal approaches including comparative site-assessment models as well as methods based on professional judgment. Some utilities and states have made progress on using comparative risk management approaches to address sites.

Implementing effective risk management strategies generally requires a sound approach and acceptance of that approach by the parties involved in the decision. Because people have different technical backgrounds, responsibilities and experiences, they may differ in their opinions regarding what constitutes a sound approach. Communication both constructive and frequent is important in reaching a common base of understanding. The development and use of RBCA and other risk management methods should facilitate this process. Technical transfer workshops and seminars can be helpful for increasing awareness in these approaches.

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Shift needed to improve market for innovative technologies

By Jacqueline A. MacDonald and P. Suresh Rao

In October, the National Research Council (NRC) will release the final version of a report that reviews the status of the groundwater and soil cleanup industry. *Innovations in Ground Water and Soil Cleanup: From Concept to Commercialization* looks critically at why the market for innovative cleanup technologies has been weak, even though $9 billion a year is spent on cleanup of contaminated sites.

It also reviews the state of development of technologies for solving a wide range of subsurface contamination problems and advises how to standardize technology testing and cost evaluation. The report concludes that a major shift in the national paradigm for regulating contaminated sites is needed to allow the market for innovative groundwater and soil cleanup technologies to function properly.

Study origins

The NRC, part of the National Academy of Sciences, began its study of innovative soil and groundwater remediation technologies as a follow-up to a 1994 NRC study of conventional pump-and-treat systems. That study found that pump-and-treat systems had been unable to achieve groundwater cleanup goals in a large number of situations. Only eight of 77 systems reviewed had achieved remediation goals.

The 1994 study also found that a combination of technical, institutional and economic barriers had discouraged development and application of alternatives to pump-and-treat systems. As a result, in 1994 the NRC began a second study to examine strategies for encouraging innovation in groundwater and soil cleanup. The NRC received funding for this effort from the Department of Defense, Department of Energy and the Environmental Protection Agency.

Innovations in Ground Water and Soil Cleanup was written by an NRC-appointed committee of 16 experts in environmental engineering, hydrogeology, soil science, environmental policy, intellectual property and finance. The committee's findings are based on reviews of technical literature and governmental reports; consultations with remediation technology developers, financiers, and federal and state environmental regulators; and the expertise of the committee members.

Limited menu of existing technologies

A major conclusion of the new report is that the menu of technologies for cleanup of contaminated groundwater and soil on a commercial scale is relatively limited. A range of technologies is available for cleanup of mobile and reactive contaminants — primarily petroleum hydrocarbons and, to some extent, chlorinated solvents — in relatively permeable and homogeneous geologic settings. See figure one, page 23.

However, relatively few technologies are available for cleaning up recalcitrant contaminants, such as PCBs, pesticides, metals, and radionuclides, in heterogeneous and less permeable geologic formations or at great depths. Even more for the easily solved contamination problems, improvements are needed to reduce costs.

Weak market for innovations

Despite the need for improved remediation technologies and the large amount of money spent at contaminated sites, the report concludes, investing in innovative technologies for groundwater and soil remediation generally is not profitable. Entrepreneurial companies founded to develop better solutions to site contamination problems have failed or lost value in most cases.

For example, the stock value of six of seven innovative remediation technology companies that have offered their stock to the public has declined since the initial public offering. Because of this poor performance, venture capital investment in start-up firms offering innovative environmental technologies declined by nearly 70 percent between 1992, when it reached a peak, and 1995.

*Continues on page 20*
The relative weakness of innovative remediation technology companies runs counter to what one would predict based on the amount of money being invested in contaminated site cleanup. Data compiled by Environmental Business International showed a spending level of $9 billion on environmental remediation in 1996 alone.

The Office of Management and Budget estimated that the federal government will spend between $234 and $289 billion on environmental remediation over the next 75 years at sites owned by the Departments of Defense, Energy, Interior, and Agriculture and the National Aeronautics and Space Administration. Predictions of the amount that will ultimately be spent on contaminated site cleanup at private- and public-sector sites have ranged as high as $500 billion to $1 trillion. This high level of spending on site remediation should result in a large profit potential for companies with new ideas for solving groundwater and soil contamination problems more effectively or at reduced cost, but with some exceptions this has not been the case.

Existing policies encourage delay

The market for innovative remediation technologies is weak in large part because federal and state policies have inadvertently encouraged delays in remediation at many types of contaminated sites. For example, the average time between when a site is proposed for listing on the Superfund National Priorities List (NPL) and completion of remedy construction was 12 years for first sites on NPL.

A recent report by the U.S. General Accounting Office (GAO) showed that administrative reforms designed to reduce this time lag have not shown measurable success and that, in fact, cleanup times have increased. The time delays have undercut the market for innovative remediation technologies by making it impossible for technology developers and their investors to accurately predict investment returns and to receive returns in the time frame necessary for the developers to remain financially solvent.

While cumbersome bureaucratic procedures have no doubt contributed to delays, the key driver, the report concludes, is the lack of clear requirements for assessing and reporting remediation liabilities on corporate balance sheets. Although the Securities and Exchange Commission (SEC) has general guidelines specifying that publicly traded corporations should disclose their remediation liabilities in quarterly and annual reports and in security registration statements, companies often fail to accurately assess and report all such liabilities.

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Many companies contend that until the cleanup goal and time line for a site are known, assessing cleanup costs is not possible. According to a Price Waterhouse survey, 62 percent of companies had known environmental liabilities that they had not yet recorded on financial statements.

Without accurately tallying and tracking remediation liabilities and including these figures on corporate balance sheets, there is little financial incentive for companies to engage in cleanup, and no amount of bureaucratic reform will eliminate all of the delays in site cleanup. It is less costly for owners of contaminated sites to postpone cleanup through litigation than to initiate remediation.

For example, the average cost to clean up a private-sector Superfund site is about $25 million. In contrast, analysis of corporate annual reports and financial statements shows that companies typically report a liability of about $1 million for sites where cleanup has not yet begun. It is less costly for these companies to maintain an annual reported liability of $1 million by litigating to delay cleanup than to begin cleanup and incur a $25 million cash drain.

Another driver for delay is inconsistent enforcement of existing regulations and the possibility that the requirements for site cleanup may change in the near future. The penalties for failing to meet existing cleanup requirements in a timely manner are not sufficient to spur uniform compliance with the regulations.

Furthermore, Congress is considering legislation that would eliminate the Superfund preference for permanent groundwater treatment remedies. Thus, site owners have a disincentive to invest in permanent treatment remedies now if the requirement for such remedies will be eliminated in the future.

Also contributing to weakness of the remediation technologies market are lack of consistent performance standards and limited freedom for customers of remediation technologies to choose their own remedies.

The GAO found that cleanup standards for groundwater and soil vary widely. The variation generally results from different decisions by regulators about future use of the land, but the factors weighed in reaching these decisions are often unclear and vary with the regulatory program and government office under which the site is being cleaned up.

For example, the GAO found that cleanup standards varied among sites that were equally near to residential areas. The lack of consistent regulatory requirements for site cleanup makes it difficult for technology developers to prove to their customers that the technology will be accepted by regulators. Without regulatory acceptance, a remediation technology has essentially no value because site owners generally are not free to choose whichever technology they believe will solve the problem best.

The report recommends a range of policy initiatives to remove the constraints on the market for innovative remediation technologies. Key recommendations include the following:

- The SEC should clarify and strictly enforce requirements for reporting of environmental remediation liabilities. This step would provide strong financial incentives for companies to clean up sites and would explicitly link prompt remediation with corporate financial self-interest.

- Congress should enact legislation allowing companies to amortize reported site remediation liabilities over a 20- to 50-year period. Such legislation would protect companies that accurately and completely report remediation liabilities from major losses in corporate stock value.

- Resources dedicated to enforcement of Superfund and Resource Conservation and Recovery Act requirements should be increased. More consistent enforcement of these major site cleanup programs is necessary to provide clear penalties for unwarranted delays in remediation.

- The EPA and state regulatory agencies should collaborate to increase the consistency and predictability of procedures for setting cleanup goals and approving remediation technologies. Increased consistency is necessary to provide technology vendors and their investors with clearer, more consistent guidelines about steps necessary to obtain

Continues on page 22 →
regulatory approval of their technologies.
- The Massachusetts program for licensing private consultants to approve remediation technologies on behalf of regulators should be considered for implementation at the national level. Implementing such a program nationally could decrease bureaucratic delays in approving site remediation technologies.
- A national contaminated site inventory similar to the Toxics Release Inventory should be developed. Such an inventory would provide added incentives to initiate site cleanup promptly to remove sites from the inventory and would provide remediation technology developers and investors with more accurate and complete information about market characteristics.

**Standard testing protocols needed**

Once the mechanisms are in place to allow the market for soil and groundwater cleanup technologies to flourish, standard methods for evaluating remediation technology performance must be developed. While other major industries, such as the pharmaceutical and automotive industries, have standard protocols for testing performance of new products, no universally applied standard protocols exist for groundwater and soil remediation technologies. As a result, evaluating the performance of new technologies relative to that of conventional technologies is difficult because the available performance data may not be directly comparable.

The report recommends that every test of an innovative technology answer two fundamental questions about technology performance:
- Does the technology reduce risks posed by groundwater or soil contamination?
- How does the technology work in reducing these risks?

Technologies reduce risks by decreasing contaminant mass, concentration, toxicity, or mobility. Showing decreases in one or more of these parameters is essential for proving technology performance, but it is not sufficient proof that the technology works.

For example, contaminant concentrations can decrease for reasons unrelated to application of technology. Sorption, dilution, unenhanced biodegradation by native soil microbes, or reactions with naturally occurring chemical substances in the groundwater can all cause contaminant concentrations to decrease regardless of the applied technology. Proving that the technology works requires data that link application of the technology with the observed decrease in contaminant mass, concentration, toxicity or mobility.

The report outlines in detail the types of data that can be used to show how the technology works for four different broad categories of remediation technology:
- stabilization, solidification, and containment technologies;
- biological reaction technologies;
- chemical reaction technologies, and;
- separation, mobilization, and extraction technologies.

In general, for stabilization, solidification and containment technologies, proof of technology performance must include data that document the mechanisms for decreased mobility of the contaminants following application of the technology and that establish the thoroughness and longevity of the mobility decrease. Proof that a solidification process works might include tests showing changes in the fluid transport properties of the solidified material, along with evaluations of the compressive strength of the solidified material, reactions to weathering, and reactions to changes in groundwater chemistry.

For biological and chemical reaction technologies, performance data must show that the groundwater and soil chemistry change in ways consistent with the reaction processes expected to take place. Reactants should be transformed to products according to ratios consistent with the stoichiometry of the governing chemical equations.

For separation, mobilization and extraction technologies, proof of technology performance should focus on documenting the transfer of contaminants to the more mobile liquid or gas phase. An increased concentration of contaminants in the more mobile phase
### Figure One: Treatment Technology Options Different Classes of Contaminants

<table>
<thead>
<tr>
<th>Solidification, Stabilization &amp; Containment</th>
<th>Petroleum Hydrocarbons</th>
<th>Chlorinated Solvents</th>
<th>PAHs &amp; Semivolatile Organic Compounds</th>
<th>PCBs</th>
<th>Inorganic Chemicals &amp; Explosives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt batching</td>
<td>X</td>
<td>na</td>
<td>X</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Biostabilization</td>
<td>X</td>
<td>na</td>
<td>?</td>
<td>?</td>
<td>na</td>
</tr>
<tr>
<td>Excavation (stabilization)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Grout walls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Lime addition</td>
<td>X(h)</td>
<td>na</td>
<td>?</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Passive barriers using</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sorption or precipitation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polymer walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pozzolanic agents</td>
<td>X(h)</td>
<td>na</td>
<td>X</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Pump-and-treat system</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>na</td>
<td>X</td>
</tr>
<tr>
<td>Sheet pile walls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slurry walls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitrification</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>?</td>
<td>X</td>
</tr>
</tbody>
</table>

### Chemical & Biological Reaction

| Biopiles                                   | X                      | na                   | X                                    | ?    | na                               |
| Bioslurry systems                          | X                      | na                   | X                                    | ?    | na                               |
| Biosparging                                | X(l)                   | ?                    | ?                                    | na   | na                               |
| Bioventing                                 | X(l)                   | na                   | ?                                    | na   | na                               |
| Chemical oxidation                         | ?                      | ?                    | ?                                    | na   | ?                                |
| Chemical reduction                         | ?                      | ?                    | ?                                    | X    | X                                |
| Engineered bioremediation (in situ)        | X                      | ?                    | ?                                    | ?    | ?                                |
| Incineration                               | X                      | X                    | X                                    | na   | X                                |
| Intrinsic bioremediation                   | X                      | X                    | ?                                    | na   | ?                                |
| Land farming                               | X                      | na                   | X                                    | ?    | na                               |
| Passive-reactive barriers                  |                        |                      |                                      |      |                                  |
| -using iron                                | na                     | X                    | na                                   | na   | X                                |
| -using organic/microbiological reactions   | X                      | X                    | ?                                    | ?    | ?                                |
| -using enhanced sorption                   | na                     | ?                    | ?                                    | ?    | ?                                |
| -using passive/active nutrient additions   | X                      | X                    | ?                                    | ?    | na                               |
| Phytoremediation                           | ?                      | ?                    | ?                                    | X    | ?                                |
| Substitution                               | na                     | X                    | na                                   | X    | na                               |
| Thermal destruction/reduction              | X                      | ?                    | X                                    | ?    | na                               |

### Separation, Mobilization, & Extraction

| Dual-phase extraction                      | X(l)                   | X                    | na                                   | na   | na                               |
| Electrokinetic systems                     | na                     | ?                    | na                                   | na   | ?                                |
| Soil washing                               | X                      | X                    | X                                    | ?    | X                                |
| Soil flushing                              |                        |                      |                                      |      |                                  |
| -acid, base, or chelating agent            |                        |                      |                                      |      |                                  |
| -steam                                     |                        |                      |                                      |      |                                  |
| -foam                                     | ?                      | ?                    | ?                                    | na   | ?                                |
| Sparging: air/steam                        | X(l)                   | X                    | ?                                    | na   | na                               |
| Recycling/re-fining                        | X                      | na                   | na                                   | na   | X                                |
| Thermal desorption                         | X                      | X                    | X                                    |      | X                                |
| Thermally enhanced SVE                     | X(h)                   | X                    | ?                                    | na   | na                               |
| Solvent extraction                         | X                      | X                    | ?                                    | ?    | na                               |
| SVE                                        | X(l)                   | X                    | na                                   | na   | na                               |

**NOTES:**
- X(h): applicable primarily for heavy fuels or high-molecular-weight solvents
- ? : application not commercially available or exists in an experimental phase
- X(l): applicable to light hydrocarbons only
- na: technology not applicable to this class of contaminants
- blank: lack of information for qualitative comparison
Figure 2: Proving In Situ Cosolvent Flushing at Hill Air Force Base

At a Hill Air Force Base site contaminated with jet fuels and chlorinated solvents, University of Florida and EPA researchers conducted a pilot-scale field study to demonstrate enhanced contaminant solubilization by in situ cosolvent flushing. Over a 10-day period, the researchers injected 40,000 liters of a cosolvent mixture — 70 percent ethanol, 12 percent pentanol, and 18 percent water — through four injection wells in a 5 m by 3 m by 10 m volume of subsurface containing non-aqueous-phase liquids (NAPLs). The cosolvent fluids, along with solubilized NAPL, were extracted through three wells. The researchers collected a variety of data, shown in this table, to establish multiple lines of evidence for NAPL removal and to link NAPL removal with the cosolvent flushing process.

<table>
<thead>
<tr>
<th>Data Objective</th>
<th>Type of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased concentrations of NAPL constituents in soil cores</td>
<td>Decreased in NAPL constituent concentrations in groundwater samples</td>
</tr>
<tr>
<td>Decreases in NAPL constituent concentrations in groundwater samples</td>
<td>Increased concentrations of NAPL in extraction fluids</td>
</tr>
<tr>
<td>Increased concentrations of NAPL in extraction fluids</td>
<td>Decreased retardation of tracers that partition into NAPLs, indicating extraction of NAPL mass</td>
</tr>
<tr>
<td>Decreased retardation of tracers that partition into NAPLs, indicating extraction of NAPL mass</td>
<td>Consistency of mass removal estimates from all of the above evaluations; all showed greater than 85 percent removal of NAPL mass</td>
</tr>
<tr>
<td>Consistency of mass removal estimates from all of the above evaluations; all showed greater than 85 percent removal of NAPL mass</td>
<td>Monitoring of contaminants, cosolvents, and tracers outside the test cell, demonstrating the effectiveness of hydraulic containment</td>
</tr>
<tr>
<td>Monitoring of contaminants, cosolvents, and tracers outside the test cell, demonstrating the effectiveness of hydraulic containment</td>
<td>Comparison of NAPL removal achieved with a conventional pump-and-treat system and that achieved with cosolvent flushing; extensive flushing with a pump-and-treat system did not lead to decreased contaminant concentrations in produced fluids.</td>
</tr>
<tr>
<td>Comparison of NAPL removal achieved with a conventional pump-and-treat system and that achieved with cosolvent flushing; extensive flushing with a pump-and-treat system did not lead to decreased contaminant concentrations in produced fluids.</td>
<td>Large rise in dissolved NAPL concentrations coincident with arrival of cosolvents in samples taken at the multilevel monitoring wells and extraction wells.</td>
</tr>
<tr>
<td>Large rise in dissolved NAPL concentrations coincident with arrival of cosolvents in samples taken at the multilevel monitoring wells and extraction wells.</td>
<td>Maximum NAPL constituent concentrations in extracted fluids consistent with predictions based on controlled laboratory studies in NAPL solubilization with the cosolvent mixtures.</td>
</tr>
</tbody>
</table>

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Figure 3: General Parameters for Template Sites for Comparing Costs of Groundwater Remediation Technologies

<table>
<thead>
<tr>
<th>Template Number</th>
<th>Depth to Water Table (m)</th>
<th>Aquifer Thickness (m)</th>
<th>Aquifer Permeability (cm/sec)</th>
<th>Groundwater Flow Rate (m/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.6</td>
<td>7.6</td>
<td>5.0x10^4</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>4.6</td>
<td>7.6</td>
<td>2.5x10^4</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>4.6</td>
<td>21</td>
<td>5.0x10^4</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4.6</td>
<td>21</td>
<td>2.5x10^4</td>
<td>150</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>7.6</td>
<td>5.0x10^4</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>7.6</td>
<td>2.5x10^4</td>
<td>150</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>21</td>
<td>5.0x10^4</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>21</td>
<td>2.5x10^4</td>
<td>150</td>
</tr>
</tbody>
</table>

NOTE: Soil porosity is assumed to be 25 percent, and hydraulic gradient is assumed to be 0.005 cm/cm for all eight cases.

Cost comparison methods needed

Just as standard methods are lacking for reporting the performance of remediation technologies, no standards exist for documenting costs of remediation technologies. Technology vendors report cost data in a variety of different formats that cannot be compared directly. Examples include cost per volume treated, cost per amount of contaminant mass removed, and cost per unit of surface area treated. Vendors also may use different assumptions about interest rates and other factors affecting costs, and these assumptions may not be stated directly. This lack of standards contributes to the difficulty of evaluating innovative remediation technologies in comparison to conventional technologies.

Even if cost reporting standards for remediation technologies were developed and followed, comparing technology costs would be difficult because differences in site conditions complicate extrapolation of cost data from one site to another. Technology costs, especially those for in situ technologies, vary with geologic, geochemical, and contaminant conditions.

To overcome the problems associated with cost comparisons, the report recommends the development of a set of generic “template sites” that can be used for initial, screening-level cost comparisons. The templates would each have standard dimensions and hydrogeologic properties. A different template could be developed to represent different types of hydrogeologic conditions encountered in the field. Figure three, this page, shows parameters for eight types of template sites. Fractured rock aquifers, which require special analysis, are excluded from this list.

Assumptions would also need to be made about the dimensions of the contaminated area. Such template sites could be used to estimate end points of the cost range for different technologies that are candidates for application at a field site with characteristics similar to those of the template site. More detailed, site-specific studies would then need to be conducted to determine precise costs.

Allowing the market to flourish

In Innovations in Ground Water and Soil Cleanup, the NRC concludes that the billions of dollars being spent each year on contaminated sites have not yielded the type of healthy, entrepreneurial market for remediation technologies that one would have predicted when contaminated site cleanup became a national priority after enactment of the Superfund law in 1980.

To more effectively solve the problems of soil and groundwater contamination, entrepreneurship in environmental remediation must be allowed to flourish. Policies that stifle innovation need to be amended. At the same time, consistent standards need to be developed for evaluating performance of new remediation technologies as they are developed in response to a stronger market.

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Write in 628

Write in 103
Tri-Service workshop presents low-cost projects at military bases

By Peter R. Guest and John W. Ratz

In June, the U.S. Army Environmental Center served as host for the second Tri-Service Environmental Technology Workshop, a training forum for technical exchange and interaction on environmental technology strategies, initiatives, demonstrations and products. Participants included personnel from the Army, Navy, Air Force and Department of Defense, as well as other federal agencies, federal contractors, academia and industry.

Among the presentations were summaries of three low-cost soil remediation projects performed under the auspices of the US Air Force Center for Environmental Excellence (AFCEE). All of the projects involved the remediation of hydrocarbon contamination at military installations.

In situ bioventing: results of three pilot tests performed at US Army Installations

US Army Environmental Center (USAEC) recently contracted with Parsons Engineering Science Inc. through AFCEE to perform bioventing pilot tests at three Army sites. The pilot sites included a former gasoline underground storage tank (UST) site at Fort Bliss, Texas; a former waste disposal pit at Fort Rucker, Ala.; and a former gasoline and diesel fuel UST site at Fort Carson, Colo.

Each bioventing pilot test consisted of initial and extended phases. During the initial phase, a vent well (VW) and several soil vapor monitoring points (MPs) were installed, baseline site conditions were characterized, and a blower system was installed and optimized.

Oxygen levels were depleted, and carbon dioxide concentrations were elevated in soil gas samples collected from fuel-impacted soils. Aerobic petroleum hydrocarbon degradation was demonstrated at all three sites. In situ respiration rates ranged from 75 to 1450 mg of fuel per kilogram of soil per year.

Air permeability testing demonstrated that oxygen could be delivered uniformly through a variety of soil types, including silty clays. Radial influence for these single-VW pilot-scale systems ranged from 9 to at least 14 meters. Although a zone of perched groundwater at the Fort Rucker site and some low-permeability soils at the Fort Carson site interfered with oxygen delivery, bioventing was generally found to be feasible at all three sites during the initial phase.

The systems installed at Fort Bliss and Fort Rucker sites were capable of providing full-scale treatment in permeable, unsaturated soils in the contamination source areas. Because the areal extent of soil contamination at the Fort Carson site exceeded the zone of influence of the pilot-scale system, the system was expanded by installing five VWs, six MPs and an upgraded blower system.

The bioventing systems installed at Fort Rucker and Fort Carson are operating for a 12-month extended testing phase to determine long-term influences of air injection on petroleum hydrocarbon biodegradation rates and concentrations in soil gas. At the end of the operating period, respiration testing and soil gas sampling will determine the degree of cleanup. Current average rates of hydrocarbon degradation are 640 mg/kg-yr and 150 mg/kg-yr at Fort Rucker and Fort Carson respectively.

One year of system operation has been completed at Fort Bliss, and year-end testing showed minor decreases in petroleum hydrocarbon levels and significant decreases in biological oxygen demand, indicating that continued operation of the air injection bioventing system would not be effective. The year-end hydrocarbon biodegradation rate for this site was 220 mg/kg-yr. Low-flow-rate soil vapor extraction (SVE) has been recommended to complete cleanup at Fort Bliss.

Unit costs, as of May 30, 1997, at Fort Bliss and Fort Rucker are less than $5 per cubic meter of soil. Unit costs are higher at Fort Carson because the system was installed in multiple mobilizations, manifold installation was required to supply air to multiple VWs in areas covered with 30.5 cm thick reinforced concrete, and two blower systems were installed. Contaminated soils here were also less permeable and at shallower depths, meaning that a much smaller volume of soil could be treated per VW.
However, a unit cost of about $26 per cubic meter is still very reasonable when compared with excavation and disposal, which could easily exceed $105 per cubic meter due to the presence of the concrete cover. Bioventing also benefits from economy of scale. For sites with more than 15,300 cubic meters of contaminated soil, capital costs of less than $7 per cubic meter can be achieved. Sites with less than 1530 cubic meters of contaminated soil will generally exceed a unit cost of $26 per cubic meter.

**The internal combustion engine as a low-cost soil vapor treatment technology**

Another low-cost technology presented at the Tri-Service workshop employed a converted automobile engine. This SVE system using modified internal combustion engines (ICEs) to extract and destroy fuel hydrocarbons is being demonstrated at many US Air Force sites. The ICE systems with advanced emissions controls were manufactured by VR Systems Inc.

Parsons Engineering, under contract to AFCEE, is collecting cost and performance data to compare ICE technology to traditional fuel hydrocarbon vapor treatment technologies and to provide recommendations for full-scale treatment, including estimates of operating and capital costs.

Among the sites being tested are three sites in Arizona and one in the District of Columbia. DREs for the four ICE systems have averaged greater than 99.9 percent.

A full-scale SVE system using ICE has operated at Davis-Monthan AFB, Arizona, for 21 months and has removed more than 317,500 kg of total volatile hydrocarbons (TVH) at an average cost of $0.31/kg. This figure includes capital costs, labor and other direct costs for operation, maintenance, and sampling including laboratory costs, and actual supplemental fuel cost during operation.

The ICE system at Luke AFB, Arizona, has removed 76,700 kg of TVH in nine months at an average cost of $0.51/kg.

At Bolling AFB, Washington D.C., the ICE system has operated for seven months and removed more than 21,300 kg of TVH at an average cost of $2.16/kg. At Williams AFB, Arizona, the ICE system has operated for four months and removed more than 90,700 kg of TVH at an average cost of $0.13/kg.

The higher costs per kilogram represent lower influence TVH concentrations and increased use of supplemental fuel as a result of decreasing extracted hydrocarbon concentrations. The TVH removal rate has ranged from 172 to 1550 kg per day and the weighted average influence TVH concentration ranged from 10,000 to 90,000 ppmv.

Vapor extraction and combustion uses an ICE with advanced emission controls to extract and burn nonchlorinated hydrocarbon vapors from the vadose zone. Vapors are extracted from the subsurface by the intake manifold vacuum of the engine via vent wells screened in contaminated intervals. The extracted vapors are then burned as fuel to run the engine. The ICE exhaust gases pass through a standard catalytic converter for complete oxidation before being discharged into the atmosphere.

The engines in the VR Systems units are modified Ford® gasoline-powered engines. Each VR Systems ICE/SVE system is equipped with an on-board computer system that provides the necessary monitoring for engine control.

External electrical power is not required for these systems because the electronic ignition is battery-powered. The ICE units are equipped with a cellular phone modem to allow for both monitoring and adjusting engine speed. The remote monitoring capability also can start the unit.

Supplemental fuel — propane or natural gas — is used to provide smooth operation of the engine as extracted soil gas TVH concentrations fluctuate. Soil vapor TVH concentrations in excess of 30,000 to 40,000 ppm, volume per volume — depending on the British thermal unit (BTU) value of the influent soil vapors — generally are sufficient to sustain the engine speed without supplemental fuel.

The on-board computer regulates the fuel requirements of the engine through a master control unit. By maintaining the proper air/fuel ratio, the TVH vapor DRE typically exceeds 99 percent, eliminating the need for air emissions permitting. The regulatory acceptance of this technology for treatment of hydrocarbon vapors in soil gas has been widespread. VR Systems Inc. ICE units have been approved for air treatment in more than 25 states.

**Performance and cost evaluation of flameless thermal oxidation for vapor-phase VOC treatment**

A soil remediation technology capable of treating both non-chlorinated and chlorinated...
Tri-Service, from page 27

hydrocarbons is FTO.

Parsons Engineering has been retained by AFCEE to perform performance and cost evaluations of a flameless thermal oxidation (FTO) vapor-phase treatment technology at four Air Force sites, including Plattsburgh AFB, New York.

The Air Force purchased a trailer-mounted Thermatrix Inc. Model GS120M FTO treatment system with a 6-hp regenerative blower and ancillary equipment. Thermatrix Inc., Knoxville, Tenn., has developed a proprietary technology for FTO of VOCs in vapor streams. The technology uses a packed-bed reactor with an inert, porous ceramic matrix designed to be resistant to moisture and acid, and non-catalytic. It has a temperature rating of up to 1370°F.

FTO technology is effective in treating chlorinated aliphatic hydrocarbon (CAH) and petroleum hydrocarbon vapors. The oxidation of VOCs in the influent vapor stream occurs in a reaction zone contained within the ceramic matrix. Typical operating temperatures are between 870°F and 1010°F. Supplemental fuel is required to maintain reactor bed operating temperatures. The system is capable of treating flow rates up to 3.4 cubic meters per minute.

System exhaust gases are discharged directly to the atmosphere, or can be routed through a caustic scrubber to remove HCl if the influent vapors contain chlorinated VOCs. The caustic scrubber was not used during operation at Plattsburgh AFB because estimated mass emission rates for HCl were less than New York State Department of Environmental Conservation (NYSDEC) annual guideline concentration for air emissions (7 micrograms per cubic meter (µg/m³)).

The FTO system was demonstrated at a former fire training area, at Plattsburgh AFB, where soils are contaminated with petroleum hydrocarbons and CAH compounds. Influent volatile organic compound (VOC) concentrations ranged from 12 to 6,000 ppm by volume. The maximum concentrations of trichloroethene (TCE) and perchloroethene (PCE) were 20 and 71 ppmv, respectively. The destruction/removal efficiency (DRE) evaluation indicated the FTO unit was 99.96 percent efficient at removing total VOCs, and between 99.98 and 100 percent efficient at removing benzene, TCE, and PCE from extracted soil vapors.

The cost for FTO system monitoring and operation for 210 days between Aug. 27, 1996, to March 25, 1997, was $73,934, which is equivalent to $352 a day. A total of 3702 kg of VOCs was removed over 139 days of vapor extraction. Treatment cost ranged from $13/kg for 139 days of vapor extraction to $20/kg for 210 days on site. Once periodic and initial mechanical problems were corrected and air flow conditions were balanced, the system was operational 96 percent of the time between Dec. 6, 1996, and March 25, 1997.

The authors of “In Situ Bioventing: Results of Three Pilot Tests Performed at US Army Installations” are: John W. Ratz, John F. Hall, David B. Teets, and Brian Vanderglass of Parsons Engineering, Denver; Gene L. Fabian, US Army Environmental Center, Aberdeen Proving Ground, Md.; and Major Edward G. Marchand, US Air Force Center for Environmental Excellence, Brooks AFB, Texas. The authors of “Performance and Cost Evaluation of Flameless Thermal Oxidation for Vapor-Phase VOC Treatment” are: Steven R. Archabal, Parson Engineering, Phoenix; Peter R. Guest, Gerald Cyn, Doug Downey and Mark Yessely, Parsons, Denver; Dave Brown, Parsons, Liverpool, N.Y.; Jim Gonzales, AFCEE/RERT, Brooks AFB; and Dan Kraft, Booz-Allen & Hamilton, San Antonio. The authors of “The Internal Combustion Engine as a Low-Cost Soil Vapor Treatment Technology” are: Archabal; Downey, Guest, and Yessely; William A. Plaehn, Parsons, Denver; and Major Marchand.
Between bacteria and fungi is a group of microorganisms generally referred to as the actinomycetes. They have characteristics of both groups. Actinomycetes produce small filaments that develop into mycelium similar to fungi. The filaments, on the other hand, are the diameter of typical bacteria. Actinomycetes produce spores and a specialized structure call a sporangium that contains spores. In some cases, these organisms have flagella, a common characteristic of bacteria.

Actinomycetes are found in all soil and are as abundant as bacteria. They occur throughout the profile. Soil with high pH, lake and river muds, and most significantly for bioremediation, compost are environments of common occurrence. In high pH soils, actinomycetes have been reported to make up 95 percent of the microbial population.

Although some are pathogenic to plants and animals, they are better known for the production of conidia, a spore form, or hyphae. If hyphae or conidia are broken into a number of smaller units these will all be counted as individual organisms. This can occur even though the amount of actively metabolizing protoplasm in the soil has not increased. Changes in the counts of actinomycetes may not be related to changes in metabolic or decomposition activity. That is, counts may show increased numbers but the rate of decomposition of organic matter or of a particular contaminant may not change.

_Streptomyces, Nocardia_ and _Micromonospora_ are the three most common genera of actinomycetes found in soil. They are in decreasing abundance as given.

By Alfred R. Conklin Jr., Ph.D.
Examples of the structure of these and other common groups are shown in figure one. All other genera are sparse in soil and thus considered to be of limited importance in soil reactions.

Numbers of organisms per gram of soil are commonly reported to be $10^5$ to $10^8$. Much lower counts are found in cold and waterlogged conditions. Actinomycetes are aerobic and thus rarely found under anaerobic conditions. Numbers become very small when soils are at 85 percent of water holding capacity or higher. Generally, populations are lower in wet than dry soils. They are also lower in cultivated soil than in grasslands and virgin sites.

Manured soils are higher in actinomycetes and the ratio of actinomycetes to bacteria is higher. Populations are generally inversely related to hydrogen ion concentration, the higher the H$^+$ concentration the lower the population. Soils with pH less than 5 are also unfavorable to their growth. if one wishes to take advantage of actinomycetes in decomposition of a contaminant it is important to keep the pH of the soil high — at seven or slightly above.

Mesophilic actinomycetes are the most common types found in soil. Mesophilic organisms grown best in the temperature range of 25 to 35°C.

There is also a genus called *Thermactinomycetes* that is thermophilic and commonly found in heating compost piles. These organisms dominate when temperatures are in the range of 50 to 65°C. However, even at these temperatures Streptomyces may be present in significant numbers and may even dominate. This is of particular interest because the rates of biological and chemical reactions increase as the temperature increases. A rule of thumb is that there is a 2x increase in the rate of reaction for each 10 degree increase in temperature.

Actinomycetes do not respond immediately to the addition of organic matter to soil. In spite of the ability to grow at high temperatures, actinomycetes are considered to be slow growers. In many natural environments, this is thought to be the result of their inability to compete effectively with bacteria and fungi.

They do not compete successfully in the decomposition of simple organic compounds such as sugars, starches, amino acids and simple proteins. Even without competition and on laboratory media they generally grow slower than bacteria. This may be because they decompose resistant material which takes longer.

Actinomycetes are effective competitors when it comes to decomposition of complex or resistant compounds. Nocardioid decompose paraffins and
phenols which are commonly used as antiseptics, steroids and pyrimidines. Micromonospora decompose chitin, cellulose, glycosides and hemicelluloses. This makes these organisms important when considering the decomposition of complex or resistant soil contaminants.

During the decomposition process complex molecules are produced. These compounds are assumed to be important in the production of humus in soil. Humus is important in maintaining good soil structure for aeration and drainage. It can also sequester both inorganic and organic contaminants and ameliorate their environmental impact.

A curious characteristic of this group of organisms is the production of volatile compounds that have very characteristic orders. For example, the smell of newly plowed soil is attributed to volatile compounds produced by actinomycetes. A compound called geosmin is thought to be the most important. Undoubtedly other compounds are also involved in production of this smell.

Some actinomycetes are involved in plant and animal diseases. The potato scab caused by Streptomyces scabies and the sweet potato pox caused by Streptomyces ipomoeae are the two best known. Infection of soil with these diseases as a result of applying compost has been reported. These organisms are commonly controlled by decreasing the soil pH. Infections in humans and animals are caused by Nocardia asteroides and Nocardia otitidis-carviarum.

The actinomycetes are an important group of microorganisms in the soil. They are of particular importance to bioremediation because they decompose complex organic compounds and they can function at relatively high temperatures. To function optimally they need a well aerated environment which has a neutral to basic pH. With the right conditions, these organisms can greatly facilitate soil remediation.

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Brownfields program works to state’s benefit in Rhode Island

By Timothy M. O’Connor, P.E., and Gregory S. Fine, P.E.

Brownfields initiatives are a relatively new approach to three old problems: the continuing decay of urban areas, the loss of rural open space, and the adversarial relationship between the business community and environmental regulatory agencies.

From 1835 until 1939, Rhode Island cities were a hotbed of the industrial age. Huge mill complexes produced products sold worldwide. These complexes have been gradually abandoned by industries, which moved to the suburbs. Today, many of these facilities remain either entirely abandoned or vastly under-used; they have become symbolic of the decay of urban quality of life.

To make matters worse, many of these abandoned properties pose a risk to their neighbors in the form of environmental contamination left behind by the former tenants.

The Rhode Island initiative

In Rhode Island, the Department of Environmental Management (RIDEM), with the support of the Rhode Island Economic Development Corp. (RIEDC), has established a program designed to streamline the site remediation process to efficiently clean up under-used, contaminated properties to allow these sites to be beneficially reused. The Rhode Island Brownfields Program accomplishes these goals by:

- developing and implementing generic, risk-based soil cleanup standards which are based on current and reasonably foreseeable future use of the property, and;
- establishing a liability system which provides a process for relief from environmental liability that can include a covenant not to sue issued by the State for innocent parties, including prospective purchasers, financial institutions and voluntary performers.

Rhode Island Brownfields Program

In March 1993, RIDEM’s Division of Site Remediation promulgated the Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases — the Remediation Regulations. These regulations were aimed at creating a more efficient version of the Federal Superfund program. The authority for the regulations was existing laws regarding hazardous waste and solid waste management, groundwater and surface water quality, and air quality.

In 1995, in an attempt to address Rhode Island Brownfields sites and stir economic redevelopment the State of Rhode Island passed the Industrial Property Remediation and Reuse Act, or the Brownfields Act. This legislation was drafted with significant input from state personnel from both RIDEM and RIEDC.

The goals of the legislations are to:

- Require the publication of numerical soil cleanup objectives which are protective of human health and the environment based on the current and reasonable foreseeable land use of a property and its surrounding natural resources;
- Allow for voluntary actions by parties other than the responsible parties, such as prospective purchasers, and insulating them from the liability normally associated with taking control of a site contaminated with a chemical release, and;
- Increase public involvement in remediation decisions.

In August 1996, RIDEM amended the Remediation Regulations to address the mandates of the Brownfields Act. This amendment process was a major undertaking, but it successfully addressed the first three directives of the legislation.

The Rhode Island Brownfields program operates under the jurisdiction of the Remediation Regulations which require all performing parties to conduct consistent and effective investigations of and responses to releases of hazardous materials. The regulations use a modified Risk Based Corrective Action (RBCA) process for responding to hazardous material releases through notification, investigation and, if necessary, remediation. The elements of the modified RBCA approach are outlined in the Risk Management section of the regulations, which establishes the requirements for response actions such that they are consistently protective of human health and the environment.

A jurisdictional release of hazardous materials occurs when analytical results indicate an exceedance of the
appropriate reportable concentrations define in these regulations. If RIDEM determines that the reported release requires a response action, the area affected by the release is considered a source area of contamination. A site with one or more source areas is considered to be a contaminated site.

In the case of Brownfields redevelopment, the Remediation Regulations are also used a guidelines for voluntary cleanups, such as those performed under the Brownfields program. Voluntary parties bear no responsibility for the contaminated site, but may realize some benefit, economic or otherwise, from remediation. Such performing parties will not proceed under an enforcement mode, but instead will be informed of the necessary procedural steps to meet the requirements of these regulations through the issuance of a Voluntary Procedure Letter.

Remediation of the contaminated site under the regulations is performed with the goal of providing permanent protection to human health and the environment. Contaminated sites are likely to enter the site management process during a phase of site investigation.

The regulatory requirement to comprehensively characterize the nature and extent of contamination at a contaminated site ensures that enough information is collected to support the consideration of remedial alternatives, and thus represents the first major step toward long-term protection. To further ensure ecological protection, the regulations specifically require the evaluation of any potential impacts to any environmentally sensitive areas at or in the vicinity of the contaminated site.

The site investigation process concludes with the selection of a site remedy or issuance of a Letter of Compliance if remedial action is not necessary. For sites requiring remedial action, the performing party must propose a remedy and provide a demonstration that the preferred alternative is protective with respect to the specific regulations.

The Risk Management provisions of the Remediation Regulations contain cleanup standards for soil and groundwater. The generic standards serve to economize cleanups as they eliminate the risk assessment phase of the site management process, which translates into financial and time savings for the performing parties.

Settlement Agreements are another component of the overall performance of the Rhode Island Brownfields Program because they represent a contract which legally codifies the performing party’s commitment to complete the approved remedy and RIDEM’s commitment to an end point in the regulatory process.

RIDEM may enter into Settlement Agreements with performing parties to perform response actions if the proposed response actions are appropriate and entering

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the agreement is in the public interest. Settlement Agreements, which may include a covenant not to sue, used in tandem with the soil standards, quantify the full extent of environmental liability up front, allowing for sound business decisions regarding the redevelopment of property.

Brownfields site remedies

Under the Rhode Island Brownfields Program, a contaminated site remedy is the result of risk management and public involvement.

The Risk Management section of the Remediation Regulations ensures that voluntary response actions continue to be risk-based by providing a tiered approach to remedial objective development.

The remedial objectives component establishes performances and concentration-based standards that are protective given the current and reasonably expected future use of the property and its underlying groundwater. The Risk Management section provides three methods for determining protective remedial objectives for hazardous substances found in soil and groundwater at any contaminated site.

Method 1 is a series of tables establishing conservative risk-based cleanup levels for common hazardous substances. Method 2 is a process by which the performing party can supplement or modify the Method 1 cleanup levels to reflect site-specific circumstances. Method 3 corresponds to site-specific human health and ecological risk assessments which may be used for assessing baseline risk and subsequently determining appropriate remedial objectives for all affected media.

Regardless of method, all remedial objectives shall be protective of human health, shall not adversely affect any environmentally sensitive area and shall not adversely affect groundwater or any other natural resource of the state.

Soil cleanup levels consider direct exposure to humans and leachability to groundwater issues. Accordingly, the direct exposure criteria are divided into residential and industrial/commercial landuse categories, and leachability criteria are divided into GA/GAA — suitable for drinking water — and GB — unsuitable for drinking water — groundwater classifications.

Integrating public involvement

When RIDEM enters a Settlement Agreement, each party’s liability for the response actions shall be limited as provided in the agreement pursuant to a covenant not to sue. The covenant not to sue may, at the discretion of the Department, be transferred to successors or assigns who are not otherwise found to be a responsible party under these regulations. The covenant not to sue may provide that future liability to the Department of a settling party under the agreement may be limited to the same proportion as that established in the original Settlement Agreement.

Before the finalization of any Settlement Agreement, RIDEM provides an opportunity for public comment for 14 days after the date of the notice of the proposed agreement. RIDEM considers any written comments, views or allegations relating to the proposed agreement. The proposed agreement is considered final when all substantive public comments have been addressed.

Public notice is also required at two points during site investigation. Before implementation of field activities, the performing party must notify all abutting property owners and tenants that an investigation is about to occur. Additionally, before formal RIDEM-approval of the site investigation report, the performing party must notify all abutting property owners, tenants and local community well suppliers that the investigation is complete and provide them with the findings and any proposed remedial alternatives.

Brownfields case study

One site benefitting from the Rhode Island Brownfields Program is the former Lincoln Dimensional Tube facility, in an industrial park in northern Rhode Island. The property was used to manufacture...
Session 1: Remediation Policy and Management Approaches I
"Exposure in Environmental Policy: Multi-Party Agreements"
"Integrating Technical Decision Making and Environmental Leadership"
"Better, Faster and Cheaper NCTR Site Investigation and Remediation"
"Using NPA Documentation to Support CVRCLA Actions"

Session 2: Remediation Policy and Management Approaches II
"Corrective Action Management Unit (CAMA) - How to Significantly Reduce Remediation Costs"
"BP’s Ranking System Scores and Risks"
"Analysis Of Innovative Technology Remedy Changes"
"Path to Reduce Requirements and Detract from Lack of RI/IFP Stygic"

Session 3: Alternative Dispute Resolution Panel (on the use of alternative dispute resolution techniques at Superfund sites)

Session 4: Children’s Health Initiative (Panel on EPA’s initiative on risk of chemicals to children’s health)

Session 5: Environmental Justice
"Environmental Justice and Agency for Toxic Substances and Disease Registry Activities at Superfund Sites"
"Ethics: Environmental International"
"For Guardsing the Homeland: What is the Integrity of Enforcement When Government itself is the Polluter?"

Session 6: ISO 14001/Environmental Management Systems
A Tool for Speeding Deployment of New Environmental Technology At Federal Facilities
Environmental Performance Evaluation and Sensor-Based Indicators
EPA-DOE, EPA, DOE, and DOE discussed the efforts of EPA administrative
Superfund reform

Session 7: Natural Resource Damages
Panel will address the Executive Order giving federal agencies other than EPA the power to issue CERCLA Section 706 orders

Session 1: Superfund Reauthorization (Panel of various viewpoints on CERCLA reform)
Session 2: EPA Administrative Superfund Reform
Panel of representatives of EPA, DOE, and DOD discuss the efforts of EPA administrative Superfund reform

Session 3: RCRA Reform (Panel of various viewpoints on RCRA legislative and rule-making process)

Session 4: Case Study: Illegal Use of a Pesticide (Panel of various viewpoints on the methyl parathion case)

Session 5: Illegal Use of a Pesticide: Media and Emergency Management (Panel on the media and emergency management aspects of the methyl parathion case)

Session 6: Pollution Prevention "Hazardous Waste Management: Mounting Challenges and Growing Opportunities"
"Manufacturing Improvements Through Pollution Prevention"
EPA, speaker invited

Session 7: EPA Responsible Party Search Process (Panel of EPA and PBF speakers on EPA’s PBF search process)

Session 8: Conflict Agendas on Brownfields
Panel of representatives of industry, municipalities, consultants, community activists, and others air their different goals for Brownfields sites

Session 9: Brownfields: State and Local Lessons
Pennsylvania’s Ground Breaking Land Recycling Program
"Brownfields Reuse in Maryland: Another State Joins The Race"
"Site Reuse/Brownfield Redevelopment in the Boston Agglomeration"
"Industrial Brownfield Case Studies Under the Massachusetts MCP and Multiple Federal Regulations"

Session 10: Brownfields: Federal Initiatives
"The Future of Brownfields: Can We Make It Work?"
EPA speakers on mature Brownfield grants and the agency’s revolving loan fund invited

Session 1: Sediment Remediation
"Remediation of Sediments By Dredging Status and Feasibility"
"Management of Dredging and Disposal Of Contaminated Sediments in New York/New Jersey Harbor"
"Practical Guidelines for Environmental Dredging Projects"
U.S. Corps of Engineers speaker invited

Session 2: Remediation of Mining Operations
Design and Construction of Geocap and Skips Stabilization of Hazardous Mine Tailings
"Field Implementation of a Novel Hydrochemistry Approach for ALE Characterization"
"Use of Lead Biodegradability Studies to Enhance Risk-Based Remediation Decisions"
BLA/EMAP speaker invited

Session 3: Building Decontaminations
Building and Equipment Decontamination Using the TechDraw Technology
"Facility Decommissioning in the Natural Gas Industry"
"Low Temperature Thermal Desorption CLean Lines Structures Contaminated with VOCs"

Session 4: Remediation of Petroleum-Contaminated Sites
Site Investigations and Diagnostic Procedures for Petroleum
"Return On Investment With A Pulsed Soil Gas Survey At a Fuel Storage Terminal"
Optimizing OCP/Recovery During Seasonal Groundwater Fluctuations
"Problem Associated With Using Biospacer Systems to Remove UNAP, from Groundwater"

Session 5: Management and Cleanup of Range Wastes
(Panel of DOD, EPA, and others to discuss EPA’s munitions rule and DOD range wastes proposal)

Session 6: Biostreatment of Explosives
"Cost and Design for Application of Composting and Bioremediation Treatment of Explosives-Contaminated Soils"
"Biotreatment Technologies for Explosives-Contaminated Soils"
"Remediation of Explosives-Contaminated Soils"
"Field Demonstration of Soil Stabilizer Bioreactor Technology for the Remediation of Explosives-Contaminated Soil"
"Non Thermal Destruction of Explosives Through Sodium Electrolysis Technology"
"A Field Scale Pilot Study for Explosives-Contaminated Soil-Versus-Lossens Learned"

Session 7: Dioxin Remediation at Times Beach
"Remediation of Dioxin Contaminated Materials at Times Beach, MD"
"Remediation of Dioxin Contaminated Materials at Times Beach, MD - Risk Assessment Issues"
"Remediation of Dioxin Contaminated Materials at Times Beach, MD - Regulatory Issues"

Session 8: Passive Remediation
"Analysis of Innovative Technology Remedy Changes"
"Speakers on chlorinated organics and phytoextraction invited"

Session 9: Containment
"Landfill Cap Remediation Project At a Former Rat Field"
"Case Study: Shurry Wall Stability Analysis and Slinky Trash"
"Closure Techniques for Soft Sludge Impoundments"
"Control of High Hydrogen Sulfide Land Emission"

Session 10: Air Sparging
"Trench Technique Failures Associated With Installation of Air Sparging System"
"Application of Air Sparging in Shallow Groundwater Setting"
"Enhancement of Soil Vapor Extraction with Radio Frequency Heating"
"Soil Vapor Extraction vs. Shovel-Circling"

Session 1: Chemical Oxidation of Soils - Session sponsored by EQ
"Treatment of Low Level Organic in Soils by Chemical Oxidation"

Session 2: In-Situ Soil Treatment
"Cored or Remediated Samples for In-Situ Stabilization/Solidification Verification Testing"
"Rapid In-Situ Removal of Chlorinated Organics From Clay Using Soil Augering and Steam Injection"
"In situ Thermal Desorption of PCBs"

Session 3: In-Situ Chemical Solidification
"Feasibility Of In-Situ Fenton Like Oxidation Of Volatile Organics: Laboratory, Pilot and Full-Scale Demonstrations"
"Zero Balance Metal Reactive Wall Demonstration/Project Results and Lessons Learned"
"In-Situ Pilot Scale Test Of An Environmentally Permeable Chemical Treatment Well at the Somerset Sanitary Landfill Superfund Site"

Session 4: New Approaches to Save Time and Money - Session sponsored by Roy J. Weston
Panel on collaborative techniques among stake holders at contaminated sites

Session 5: Risk Assessment
"Performance Assessment for Environmental Decision-Making"
"Ecological Screening Methodology for Risk
Opening Plenary Session

Exhibit Viewing

Superfund Reauthorization
(Panel of various viewpoints on CERCLA reform)

Sediment Remediation
Passive Remediation
Groundwater Remediation
Financial Issues in Site Remediations

Lunch-Exhibit Viewing

EPA Administrative Superfund Reforms

Remediation of Mining Operations
Containment
Groundwater Remediation and Enhanced In-Situ Remediation I
Incentive-Based Contracting

RCRA Reform

Building Decontaminations
Air Sparging
Groundwater Remediation and Enhanced In-Situ Remediation II
Mergers and Consolidations

Meet the Speakers Breakfast

Case Study: Illegal Use of a Pesticide

Remediation of Petroleum-Contaminated Sites
Physical Treatment of Contaminated Soils
Groundwater Investigation I
Pricing the Changing Role of the Industry Environmental Manager

Exhibit Viewing

Illegal Use of a Pesticide: Media and Emergency Management

Management and Cleanup of Hazardous Wastes
In-Situ Soil Treatment
Groundwater Investigation II
Insurance Issues

Lunch-Exhibit Viewing

Pollution Prevention

Bioremediation of Explosives
In-Situ Chemical Solidification
Groundwater Investigation III
Information Management

EPA Responsible Party Search Process

Disin Remediation at Times Beach
New Approaches to Save Time and Money
Passive Soil Gas Sampling
Internet Use

Conflicting Agendas on Brownfields

ENR's Superfund Owners Forum
Risk Assessment
Remedy Selection
Post Cleanup Matters

Brownfields: State and Local Lessons

Brownfields: Federal Initiatives

Lunch-Exhibit Viewing

Management Planning
"Innovative Risk Assessment Procedure for a Former Munitions Manufacturing Facility"
"Moving from a Risk Assessment to a Risk Management Decision"

Session #9: Remedy Selection
"Case Study Comparisons of Vapor Infiltration Risk Estimates: ASTM RCRA Model Predictions vs. Site Specific Soil Vapor Data"
"A Regional Perspective of Community Based Remedy Selection"
"The American Crossroad Experience"
"Corporate Remedy Selection Using Financial Modeling"

Session #10 Post Cleanup Matters
"Ensuring Protectiveness of Human Health and the Environment of Superfund Sites: The Five Year Review" * EPA speakers invited

Track F - Groundwater Remediation

Session #1: Groundwater Remediation
"Pneumatic Pumping System: Selection, Design, Control and Filter Test"
"A Dual Use UF and UF System to Remediate VOC and Pesticide Contamination of Groundwater at a South Georgia Landfill Site"
"Case Study: Passive UNAP, and DINAP, Recovery in a Subsurface Vadose Zone"
"Pilot Testing Develops Dual Phase Extraction Design Requirements at a Superfund Site in VA"

Session #2: Groundwater Remediation and Enhanced In-Situ Remediation I
"NITVOC - An Innovative Solution for Contaminated Groundwater Remediation"
"An Overview of In-Situ Vertical Groundwater Circulation Well Technologies"
"Reactivity Testing Points Toward Innovative In-Situ Approaches to Eliminate Subaqueous Generation and Disposal Costs"

Session #3: Groundwater Remediation and Enhanced In-Situ Remediation II
"In-Situ Enhanced Bioremediation of Jet Fuel Contaminated Soil and Groundwater"
"In-Situ Remediation at On ANE Using the UB Technology"
"Interceptor Trenches Enhance In-Situ Bioremediation in Shallow Water Table Aquifer"

Session #4: Groundwater Investigation I
"Use of Constituent Proportions and Isotopes to Characterize Contaminant Plumes"

Session #5: Groundwater Investigation II
"Geoprobe Electrical Conductivity Logging to Map Subsurface Geology Comparison to Conventional Split Spone Sampling Techniques"

Session #6: Groundwater Investigation III
"Comparison of Geoprobe Proskopaged Screen Wells to Panel has 2" PVC Wells"
"Lessons Learned a History of Site Characterization"
"Analysis of Groundwater Remedial Options - Analytical and Numerical Modeling"

Session #7: Passive Soil Gas Sampling
"Return on Investment Through Integration of a Passive Soil Gas Survey at a Chemical and Solvent Distribution Facility"

Session #8: Remediation Monitoring with Passive Soil Gas Sampling
"Rapid Site Assessment Applied to the Florida Department of Environmental Protection's Dry-Cleaning Solvent Cleanup Program"

Track G - Business and Information Issues

Session #1: Environmental Issues in Site Remediation
"Potential Applications of Financial Assurance in Nations that have Emerging Industrial Economies"

Session #2: Revenue Enhancement
"Remediation Cost Estimating and Documentation: An Integrated Approach to Understanding Cost Methods and Principles for Superfund Remediation Actions"

Session #3: The Changing Role of the Industry Environmental Manager (Panel of speakers from EPA, DOE, and states on cost-performance contracting)

Session #4: Mergers and Consolidations (Panel of speakers on company mergers and consolidations as the remediation industry and what the future holds)

Session #5: Cost Management (Panel of speakers from manufacturing firms on cost-reduction programs, successful alliances and partnerships, and strategic environmental management issues)

Session #6: Cost Management (Panel of speakers on addressing insurance changes in the market place)

Session #7: Geographic Information Systems: Use in Environmental/Public Health Studies
"Other speakers invited"

Session #8: Internet/Ive
"Superfund Resources on the Internet"
"Making Hazardous Waste Information Available - Lessons Learned from the Superfund Internet Web Site"

DOD speaker invited
Industry-DOE partnership leads to successful project deployment

By Jeff Kulpa, Michael Mann, Ward Best, Michael Hightower, Dale Pflug, and Michael Krstich

The Department of Energy (DOE) has initiated a project that deploys soil treatment technology to support its cleanup of a site in Ashtabula, Ohio. This deployment integrates the efforts of a prime contractor, private industry, and two DOE programs into a decisive path forward for remediating uranium contaminated soils.

This undertaking is the culmination of many years of effort by private industry and the DOE to implement treatment technology for remediating contaminated soils. RMI Environmental Services (RMIES) and Alternative Remedial Technologies (ART), with the assistance of two DOE programs, Innovative Treatment Remediation Demonstration (ITRD) and Technology Connection (TechCon), deployed a soil treatment technology to the RMI Titanium Company (RMI) site in Ashtabula, Ohio, to replace off-site shipment of the uranium-contaminated soil to a disposal facility.

Location and background of the Ashtabula site

The Ashtabula site is a 10.5-hectare site in the highly industrialized area of Ashtabula County in northeastern Ohio, about 1.5 kilometers south of Lake Erie and 3 kilometers northeast of the center of the City of Ashtabula. RMI operated an extrusion plant at this site from 1962 to 1988 to process uranium metal into forms useable by the DOE in nuclear and non-nuclear weapons production.

The uranium metal processed at the site included depleted and slightly enriched material that was subsequently shipped to weapons production reactors.

During uranium extrusion and machining, particulate uranium was emitted from roof vents and stacks to the surrounding soils. Characterization studies indicate that about 31,750 metric tons of soil are contaminated above the treatment standard for uranium. The Decommissioning Plan submitted to the Nuclear Regulatory Commission (NRC) in April 1995 establishes 30 pCi g⁻¹ as the cleanup level for total uranium in soils.

A change in the remediation concept

Due to the clay-like nature of the Ashtabula soil, a site evaluation concluded in 1990 that soil treatment was not a candidate in the remediation of these soils. Until 1995, the preferred remedy was excavation, packaging and transportation to an approved off-site disposal facility for burial. Clean soil would be purchased and spread to replace the excavated soil. Total cost of the soil remediation was projected to be $27 million.

It was during this time period (1991 to 1995) that extensive treatability testing was conducted within the DOE for treating uranium-contaminated soils. Uranium-contaminated soils from the DOE-Fernald site in southwestern Ohio were targeted by numerous programs within the DOE to evaluate the effectiveness of physical and chemical treatments for removing the uranium from the soil. Based on this extensive test program which included national laboratories and a number of large environmental engineering firms, soil treatment using a combined physical/chemical treatment process emerged as an effective approach in removing uranium from soils.

In August 1995, RMIES contracted with ART, a commercial soil washing company, to evaluate the technical feasibility for a physical/chemical treatment approach at the Ashtabula site. This soil treatability initiative showed that by using physical separation and chemical extraction, a high percentage of uranium could be removed from the bulk of the soils. The concentration of uranium in the soil could be reduced by 85 to 90 percent and thereby allow the recovery of a high percentage of the soil that passed the targeted clean-up standard. An initial cost-benefit analysis showed that processing soil could result in significant cost savings for the site cleanup. However, the risks of making such a decision were considered a significant barrier to moving forward with deploying soil processing at the Ashtabula site.

Continues on page 40 →
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Cooperative support within the DOE

The successful deployment of soil treatment capabilities to the Ashtabula site has been partially due to cooperative support within the DOE. Two separate programs that support DOE's restoration efforts provided technical support necessary for deploying soil treatment technologies. And a collaborative effort between two DOE sites has resulted in the transferring of equipment and technology to the Ashtabula site.

The two DOE programs within the Office of Environmental Management (EM) that supported RMIES in deploying beneficial new approaches at the Ashtabula site are ITRD, out of Sandia National Laboratories, and TechCon, based at Argonne National Laboratory. Both programs were instrumental in facilitating the deployment of soil processing at the Ashtabula site by providing technical and financial support needed to proceed with the technology.

The DOE at the Ashtabula site established a working relationship with the DOE-Fernald site that supported this soil remediation effort. The soil washing pilot plant (SWPP), once used to test the technologies effectiveness for treating uranium-contaminated soils at the DOE-Fernald site, was transferred to the Ashtabula site. Portions of the SWPP were used in construction of the pilot plant at the Ashtabula site. The significance of this activity represented not only a transferred of excess property between two DOE sites, but the transferred of technologies within the DOE complex.

Deployment of a soil treatment technology

In late 1995, the TechCon Program began working with RMIES to explore new technical approaches for treating soil at the Ashtabula site and facilitating interactions that would ultimately lead to the deployment of beneficial soil processing.

TechCon's in-depth understanding of the barriers associated with deployment of soil treatment technologies was a result of their interactions at numerous DOE sites as well as their significant interactions with commercial vendors to support privatization initiatives. TechCon's experience and insight on previously unrecognized opportunities provided important support guidance to RMIES in the path forward to establish soil processing capabilities at Ashtabula.

By early 1996, RMIES had decided on the soil treatment system's configuration for the Ashtabula site. They requested that ART, a Tampa, Fla. soil washing company and a joint venture between Geraghty &
Miller Inc. and Heidemij N.V. (Heidemij) of the Netherlands, assist in this effort. The establishment of ART in 1992 brought to the United States Heidemij's soil washing approach which has successfully remediated more than 453,500 metric tons of soil in the past 15 years.

RMIES/ART's decision to proceed with beneficial soil processing was contingent on the successful application of an approach called Process Definitive Testing (PDT) to determine the potential for providing a performance-based cleanup. Standard PDT includes a pilot plant operation to confirm final process steps, economics, and reduction of production-plant uncertainties to an acceptable risk level.

It was at this point in the effort that the ITRD program became instrumental in RMIES/ART's operations. ITRD, which was supporting technology demonstration activities at other DOE Ohio Field Office sites, supported the RMIES/ART collaborative team and helped fund the PDT activities conducted in June-August 1996. The remaining funding was supplied by the DOE at Ashtabula and DOE Ohio Field Office, along with RMIES/ART contributions.

ITRD once again helped fund the pilot plant operation conducted during late December 1996 and January 1997. The processing approach, derived during PDT, narrowed on using elevated temperature carbonate extraction to treat the soil. The processing data and cost-benefit analysis from the operation of the pilot-scale effort, suggested that full-scale production plant operations would be practical and cost effective. The identified full-scale treatment system will use performance-based contracting to provide incentives to the RMIES/ART team while meeting DOE contract improvement goals.

A description of the soil treatment process

Since the Ashtabula soils consisted predominantly of clay, chemical extraction was selected as the primary treatment process. The chemical treatment process evaluated was designed to leach uranium from contaminated soils using a sodium carbonate/sodium bicarbonate extraction process. The process flow

Continues on page 42 →
Ashtabula, from page 41

diagram for the pilot-scale system, which operated in batch mode to treat about 58 metric tons of uranium contaminated soil, consisted of (See figure 1, page 40):

- A rotary batch slurry reactor in which a heated carbonate solution is contacted with feed soils.
- A wet-screen for removing the oversize soil fraction.
- Thickener for liquid/solids separation to remove the uranium-loaded carbonate solution from the bulk soils.
- A filter press for dewatering treated soils.
- An ion exchange system to remove the extracted uranium from the carbonate solution.
- A precipitation reactor vessel for removal of uranium into a "yellowcake" product.

The project confirmed that Ashtabula soils could be effectively treated for uranium removal by using a 0.2 molar sodium carbonate/bicarbonate extraction at 45°C, with an effective retention time of 1.5 hours. On the average, the pilot plant achieved the following results:
- 85 percent uranium removal efficiency.
- 95 percent volume reduction.
- Effectively treated most soils to less than the treatment standard of 30 pCi g⁻¹.

The cost for the pilot project totaled $636,670, with the most significant costs associated with procurement of capital equipment, plant operations, and laboratory analyses. Based on the associated direct costs, it is expected that eventual full-scale production costs for soil washing plant operations will be $328 to $460 per cubic meter of soil. The cost of soil treatment shows significant savings over the initial preferred remedy of off-site transportation and disposal.

Establishment of a facility at the Ashtabula site

Based on this pilot-scale project, the DOE at the Ashtabula site has determined that processing of soil to reduce the volume of contaminants before off-site disposal will be beneficial in achieving significant cost savings and accelerating cleanup schedule. Because of a unique combination of facility resources, operating experience of the participants and deployment strategies, the site is an excellent candidate for success in a new mission built around providing processing services for contaminated media from other sites.

This cooperative effort between government and private industry is a result of many years of effort to implement soil treatment technologies within the DOE complex. Since cost is the primary driver for the implementation of a selected remedy, soil treatment technologies must be cost competitive with disposal options. The beneficial soil processing project at the Ashtabula site has demonstrated that a soil treatment technology is practical and cost effective.

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Write in 427
Catalytic Combustion Corp.
Catalytic Combustion Corp., Bloomer, Wisc., offers the Express line of catalytic oxidizers. The units feature a low temperature oxidation catalyst. The line also features heat recovery, compact footprint, auto dilution, temperature and air flow recording and process blower.

NAO Inc.
NAO Inc., Philadelphia, offers a line of portable thermal oxidizers. These trailer-mounted units feature a maximum capacity of 55,000,000 Btu/hr and maximum operating temperatures of 1260° C. The units are available in a variety of configurations and modifications.

Global Technologies
Global Technologies, Milwaukee, offers the Global Remedi-Cat or the Chloro-Cat catalytic oxidizer. The units use an internal heat exchanger to recapture the energy from the VOC oxidation and are self-sustaining. Systems are available in standard or custom sizes.

E Products Inc.
E Products Inc., St. Paul, Minn., offers the Venturi Thermal Oxidizer. The unit uses the fume stream as the fuel source, is controlled by temperature, and uses ceramic, venturi shaped burner tiles. Flame arrester, strip chart recorder, skid and exhaust stack are included in the price.

King, Buck Technology
King, Buck Technology, San Diego, offers the HD CatOx™ system designed to destroy chlorinated VOC from SVE, air strippers, and end-of-pipe processes with effluents containing chlorinated compounds. The unit’s DRE is ≥99 percent, according to the manufacturer.

Falmouth Products Inc.
Falmouth Products Inc., Falmouth, Mass., manufactures the FALCO 100, which treats flows from 40-120 CFM, and the FALCO 300, which treats flows from 100-330 CFM. Standard features include automatic dilution control, flame arrester, and integrated heat exchangers with catalyst. Optional blower packages are available.
Rhode Island, from page 34

brightened copper and nickel tubes from 1964 to 1986. Waste disposal processes during the operation of the facility used an on-site sludge bed and treatment lagoons.

In April 1996, a prospective purchaser, Weeden Street L.L.C. (WS), approached RIDEM and RIEDC with a proposal to purchase the property and renovate it. WS owned and operated a facility in Rhode Island and a facility in Massachusetts and desired to consolidate to one location. The proposal hinged on resolving environmental issues in an expedited manner and negotiating a settlement of the $330,000 in owed property taxes.

In September 1996, RIDEM and WS entered a Settlement Agreement which included a covenant not to sue. In December 1996, RIDEM issued WS a Letter of Compliance approving their remedy.

The benefits of the Brownfields program to Rhode Island in this project included:

- the transfer of 40 to 50 jobs from a Massachusetts facility to Rhode Island;
- keeping a Rhode Island based company in the state;
- $60,000 to $75,000 per year in state income taxes;
- payment of back and future property taxes to the municipality.

**Brownfields future**

In August 1996, Rhode Island passed the Mill Building and Economic Revitalization Act. This statute provides economic incentives for the beneficial reuse of industrial building built before 1950. These incentives include property tax, inventory tax and other tax relief to owners and operators which meet specific criteria. Eligible sites will be nominated by the respective municipalities by December 1997.

RIDEM received a USEPA Brownfields Pilot Grant and has worked with USEPA to more effectively use traditional sources of funds. This has allowed RIDEM to conduct Phase I and Phase II environmental site assessments to jump start potential Brownfields sites that are abandoned or too complicated for the more common private sector financed programs.

RIDEM is currently working jointly with the private sector to extend the benefits of the Brownfields program to petroleum sites through amendments of the Brownfields law. Several private environmental and land holding companies, including ERM, are investing Brownfields projects directly through equity ventures. These ventures can include in-kind contributions, joint ventures with developers or outright purchases.

The Brownfields program is working in Rhode Island because of the cooperative relationship between RIDEM, RIEDC and the regulated community. This relationship is the result of the cooperative effort in writing the Rhode Island Brownfields Act, a Rhode Island Brownfields conference held in October 1995, brainstorming workshops held regarding the amendments of the Remediation Regulations and RIDEM's overall commitment to use the command and control approach to site cleanups only when all voluntary options fail.
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To install, drill the appropriate sized hole for the StrataSampler. For example, drill a hole greater than or equal to 100 mm diameter for a 50 mm diameter StrataSampler if a sand and gravel pack is used.

Install the StrataSampler by inserting one section at a time into the borehole annulus, keeping in mind that the unit must be threaded to the various sections of the well casing.

Fill in, using tremie pipe, the appropriate sized sand, gravel pack and bentonite in the annulus.

Repeat this procedure for as many StrataSamplers as are to be installed in each borehole.

Add a bentonite plug, grout to the surface and install a well pad according to specific state regulations.

Multiple StrataSampler ports can be placed in a single borehole to allow collection of discrete samples from several different depths. Multiple samples at various depths can be collected simultaneously. It also can be used to monitor the surface water and groundwater interaction in wetlands, rivers and streams.

The device consists of a stainless steel wire wrap, screened, chamber of 50 mm in outside diameter with a stainless steel inner sleeve, and a 13 mm tubing connection. A variety of pumps can be used to collect samples from the 13 mm collection port.

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