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* Abbreviations and acronyms:
  AST - above-ground storage tank
  BTEX - benzene, toluene, ethylbenzene
   and xyleno
  CERCLA - Comprehensive Environmental
   Response, Compensation and Liability Act
  EPA - U.S. Environmental Protection Agency
  GC - gas chromatograph
  MCL - maximum contaminant level
  MS - mass spectrometer
  MSDS - Material Safety Data Sheet
  ppm - parts per million
  psi - pounds per square inch
  RCRA - Resource Conservation and Recovery Act
  SVE - soil vapor extraction
  UST - underground storage tank
  VOC - volatile organic compound
A vitrified block is lifted for inspection in phase two of the project.
A toast, mate, and a glass for the Commonwealth

Melting radiological soil contaminants into vitrified blocks keeps plutonium down underground in the Australian Outback

By Steve E. Roberts, P.E.

The Outback is home to aborigines, kangaroos, huge spiders and deadly snakes. The soil at the Maralinga site is contaminated from British nuclear weapons testing. The Australians want the area cleaned up so human exposure to plutonium (Pu) is reduced. The Maralinga Test Range is far from home unless you’re native to the Australian Outback. In the Great Victoria Desert of South Australia, Geosafe project manager Leo Thompson intends to vitrify contaminated soil—to turn it into glass by melting it.

To lower aboriginal people’s risk of Pu exposure, Geosafe Australia Pty. Ltd., a subsidiary of Geosafe Corp., Richland, Wash., has contracted with the Commonwealth of Australia to clean up the former nuclear test site. In-situ vitrification, or ISV, is the technology to be employed. This interview was conducted by telephone just days before Leo and his family flew to Australia to live for the next two to three years.

The Thompsons left toward the end of summer. Now, it’s already approaching summer solstice, down under, with temperatures in the desert sometimes 45 to 50°C. “The last day we were there last year,” Leo says, “I was sampling some radioactive blocks. I had on a respirator, coveralls, gloves, the whole nine yards, and it was 110 degrees (43°C). And that was in spring, in October.”

Leo Thompson is managing director of Geosafe Australia Pty. Ltd. A full-scale ISV plant is to be constructed and used to treat 21 burial pits at Maralinga’s Taranaki area. The Maralinga site was used for above-ground testing of nuclear weapons by the British in the late 1950’s and early 1960’s. A series of minor trials (non-nuclear detonations

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Australia, from page 7

Four electrodes at corners of molten soil at appx. 1950°C. The white material is insulation to reduce heat losses.

of devices using conventional high explosives) resulted in extensive contamination of the Taranaki area, with substantial volumes of buried waste and debris. Soil is contaminated with Pu from radioactive fallout. Snakes, wild dogs (dingos), and huge spiders add to Leo’s logistical endeavour (British spelling). We’ll get to that shortly.

A simple overseas phone call from Australia can be an involved chore. It’s 17.5 hours difference between South Australia and the Pacific Time Zone, for in addition to the International Date Line in the middle of the Pacific Ocean, the South Australians add, for good measure, an extra 30 minutes to their clocks. Leo’s project is but two time zones away from being halfway around the world from, say, New York. But time differences are easy to overcome compared to remediating soil in the Australian Outback, 800 km from the nearest hardware store.

“Maralinga itself is a large site, about 3200 km²,” Leo says. “There is a place called Maralinga Village. At one time there were about 2000 workers, back when the British were testing the nuclear devices.
"There are actually two prongs to the overall project. One is ISV, to treat contaminated debris and soil buried in 21 pits at Taranaki. Debris around the Taranaki site, where the devices were detonated, were pushed into pits and buried immediately following each detonation. That’s the ISV part. The other is to clean up contaminated surface soil,” Leo says.

"Essentially, they’re going to scrape up the contaminated surface soil, put it in a big hole in the ground, and bury it. Plumes of contamination extend for miles from the fallout. The idea is to scrape the most heavily contaminated areas and place that contaminated soil in a large vault."

Was the pit that they put the debris in a crater from the bomb detonation?

"No, not at Taranaki. They (the British) generally dug out a hole before hand, or used conventional explosives to create a pit, because the ground is very hard, largely limestone and dolomite. The digging was difficult. Then they would detonate the device, and afterward blade everything into the hole,” Leo says.

What’s driving the project?

"It’s the semi-traditional aborigines who live in the area, and by that I mean several thousand square miles. Because of their lifestyle, they are more likely to ingest or inhale the contaminants, because they sit on the ground, they sit around campfires, and they tend to inhale more dust than you or I would just by walking through the site. Our risk (for contamination) would be lower.”

Leo describes wildlife native to South Australia. He mentions poisonous snakes called Death Adders that “really have an attitude.” He describes hordes of ants that engulf test equipment. He describes billions and billions of buzzing flies. Leo vividly relates experiences with hairy spiders 15 cm (6 in.) across, foot to foot, that inhabit the portable showers. Dingos he portrays with primitive, hunger looks in their eyes.

"There are Camels,” Leo says, "brought to Australia just in the last century. Now they’re wild. They come around the site and occasionally cause trouble—like knocking over fences. And birds.

Gorgeous birds—just phenomenal. All kinds of parrots. Pink and white with beautiful plumage.

"We came out of a building in Canberra, a couple of trips ago, there must have been 500 cockatoos across the street in a park. They’d just landed. They make an awful racket. And, I suppose to an Australian, it’s like seeing a bunch of crows or something. Or a robin—nothing new to them."

Leo says when you fly in to the Maralinga site, it appears very green, from the low-growing trees about ten feet tall. It looks like a forest from the air, but it’s a desert. "Towards the northern part of the site, where the forward areas are, the appearance of the site changes. At Taranaki, about 100 yards from ground zero there is a tree about 20 feet (6 m) tall,” Leo says. "There’s really not much vegetation at Taranaki—just scrub."

The soil, from your pictures, looks orange. Why?

"I’m not a geologist, but when I first saw it I thought it might be associated with high iron content. But there isn’t much iron in the soil. It’s a fine, powdery sand with about two percent-by-weight iron oxide."

You’re a chemist by education?

"Yes, I received a B.S. in chemistry from Western Washington University in Bellingham, a beautiful city. Right out of school I got a job with Battelle Memorial Institute at the Pacific Northwest National Laboratory in Richland, Wash. I started out in school, took a couple of years off, realized school was the way to go, and I was 24 or 25 when I got my degree. I worked in lumber mills, and all kinds of things.

"Literally, the only time I have ever run for my life was in a lumber mill. Leo describes a 12-inch band saw blade, 30 feet long, coming off its pulleys, right at him, as if it were attacking him.

"I worked in quality assurance (QA) for a few years at Battelle, assigned to a wide variety of projects. One of my assignments was to work in the Waste Technology Center, which included ISV. Then I transferred from QA to work directly in the ISV Group, where I worked for a couple of years. Then through fate or good fortune I found myself group leader. I was involved with applications being developed for INEL (Idaho National Engineering Laboratories), Oak Ridge, Savannah River, and other Department of Energy (DOE) facilities. I also was involved in projects for non-DOE clients, the Navy, and so forth. But ISV was always my first love,” Leo says.

"After being in the ISV group for a few years, I joined Geosafe specifically to handle the Australian project. At that time that Australians had settled with the British to obtain funding to conduct the cleanup."

Leo, at 38, is about to transplant himself, his wife, Ruth Ann, and two school-age children, Lucas and Allyssa, to South Australia. Our conversation includes school uniforms, Australian pronunciation of letters Z and H (zed and haych), and the dearth of Egg-brand frozen waffles, a staple in his son’s American diet.

"I’ve been to Australia about ten times. The family has been there only once. I took them to Australia earlier this year when it was apparent this contract was imminent and that we would be moving. We spent a week in Adelaide, and a week in Sydney."

Sydney, host of the Olympics in 2000, is on the southeast coast of Australia. The Maralinga site is in south-central Australia. See map, page 8. We discuss the area around Maralinga.

"There is absolutely nothing at Watson except a siding. When we drove up to Watson I thought there would be something there. There are no buildings. No nothin’. And I don’t think there is even a gas station in Cook. The nearest town of any size is farther south, you see that? Ceduna? Almost right on the coast."

There it is. Ceduna. A small dot.

"That’s 400 km from the site,” Leo says emphatically. "Just a few thousand people, at most.” Leo sounds like he’s about to travel to Antarctica. "There’s not much else out there."

Logistically, you have to get all your..."
Australia, from page 9
gear out there. Diesel for generators, water, food, everything. How often will you be supplied by plane or convoy?
"We’ll try to get everything we need to begin with out there, in terms of supplies. But it’s difficult to say right now how often we will need to have supplies shipped. We’ll have things come out from time to time by truck, as the crew comes out periodically by plane, or as the diesel fuel is delivered. A separate contractor manages the camp and mess so they have to arrange for food supplies."
You’re going to have a pretty large tank farm for your reserve supply of diesel, aren’t you?
"We’ll have at least one or two rail cars sitting on the siding so that we have a nearby reserve. That siding is around 75 km from the site, at Watson. Then we’ll have another tank farm up at the site."
How do you get your water?
"The groundwater at the site is all heavily saline and brackish. In the village, for potable water, there are a couple of options. The reverse osmosis plant works fine. However, historically, what they’ve done is to collect water from the airstrip runway that the British built. It’s a paved runway. The Australians have installed around the runway a series of ditches and canals. To call these ditches ‘canals’ is being quite generous. When it rains the water runs into the ditches, then into a reservoir, and then it’s pumped into a settling tank. It’s used for drinking water.
"It doesn’t rain at the site very often. Maybe once or twice a year. In some years it doesn’t rain at all. But when it does rain it usually comes in sheets."
So the only treatment to the water is the settling tank?
"Yes. But I tell you, the water is wonderful. It tastes great. It’s amazing, really. I have to admit, when I was first told it was runway water, I was skeptical. But it’s good water. Must be the lizard droppings or something," Leo says casually.
What is the history of ISV?
"Initially all the development work was focused on DOE work at Hanford for transuranic-contaminated soils," Leo says. Transuranic describes isotopes of elements heavier than uranium.
"After several promising tests and demonstrations at both small and intermediate scale, a decision was made to do a full-scale demo, so a large-scale ISV machine was designed and built by Battelle, and it was funded by DOE. The first large-scale radioactive demonstration was conducted in 1987 at one of the sites at Hanford, a crib called the 216-Z Crib. It was like a trench, or a French drain.
"I was involved in quality assurance issues for the ISV Group at that time. Their research determined that ISV could be applied not just to DOE sites, but to various industrial waste sites. So the focus broadened in the mid-80’s to include heavy metals and organics, and a lot of tests were done, including demonstrations on PCBs and industrial sludges. The development continued in both areas, in both DOE areas and in hazardous waste."
The ISV process was invented by Battelle in 1980, and patented in 1983 according to Leo. He says the Australians first considered it for their application in the late 1980s.
"The Australians liked the idea of using ISV on the Taranaki pits because the process is capable of treating in one step the range of contaminants and debris buried in the pits. It provides a permanent solution.
"The public perception of ISV is very positive. They support it. They like the idea of treatment in the ground, where you don’t have to dig the waste up, you don’t have to haul it through town. You don’t have to put it in somebody else’s backyard, so to speak. They seem to like the process."
Leo says the regulatory acceptance of ISV has been good, because of the performance characteristics. "I haven’t met a regulator yet," Leo says, "who isn’t satisfied with the effectiveness of the process immobilization and the effectiveness in destruction of organics. In particular, ISV is very effective on difficult sites involving multiple contaminant types and debris. Generally, we have a high level of regulatory acceptance.
"One thing that attests to that is the TSCA (Toxic Substances Control Act) demonstration project, treatment of PCBs in Spokane, Wash. Folks at EPA headquarters were very pleased with our performance. We received a national TSCA operating permit allowing Geosafe to treat PCB-contaminated soil up to 18,000 ppm."
Do you have to satisfy mostly American regulations and standards, or those of the Australians? Or the British?
"The Australians are really the only people that we have to satisfy in terms of regulations. The overall project is being managed by the Commonwealth Dept. of Primary Industries and Energy. What they generally do is rely on the IAEA, the International Atomic Energy Agency, for things like occupational exposure limits, safe practices, and so on.
Do you have health physicists on site?
"Yes, there is another contractor who takes care of that. CH2M Hill won the contract for on-site health
physics support. The Australian Radiation Laboratory is the health physics regulatory agency."

Does everyone wear a dosimeter?
"Actually, in the past they did. But at this site, because of the hazard from Pu, it’s an inhalation hazard, the dosimeter really doesn’t do that much for you. Pu primarily gives off alpha radiation."

On to the logistics of the project. You’re entering the third phase of a four-phase project. What have you done so far?
"Phase One was preliminary evaluation. We traveled to the site. Did a site assessment. We collected a bunch of soil samples, with the assistance of some Australian organizations. Then we shipped the samples to the U.S. and did some tests on them, including small-scale ISV melts. We had crucible melts, and we measured viscosity and electrical conductivity for various melted soil mixtures. We looked at all sorts of things to evaluate how ISV might work at the site. That was Phase One.

"Phase Two was to conduct a series of tests and demonstrations, including two radioactive demonstrations. The main objective was to collect specific data on how the process would behave on various configurations of soils and wastes that we expected to encounter at full-scale. The climax of that effort was the radioactive tests, where we put in a scaled amount of debris, a kg of UO2 in each test and, in one test, a steel plate contaminated with about 0.5 grams of Pu. We had the two vitrified blocks result from the demos that weighed about four tons apiece (3600 kg). This was all done last year.

"An interesting challenge is that there are no hardware stores near the site. If you need a nut or a bolt, you have to get on a plane and fly 800 km to get it."

Let’s talk power. Is 5 Megawatts (MW) the largest ISV unit around? Are there bigger units available elsewhere for other projects?
"This is the largest ISV unit that will be in existence. Previous units have been designed for a nominal power level of 3.75 MW. We decided to go with 5 MW for a couple of technical reasons. Non-technically, you might say that we wanted to have a little more ‘punch.’"

Does having metal, contaminated debris or otherwise, in the pathway between the electrodes hurt or help the vitrification process?
"It really doesn’t hurt. What happens is this: if two or more electrodes actually touch metal, then you have a low-resistance pathway, which results in a short circuit. When you have a short circuit the amperage goes to full scale, and the voltage drops to essentially zero. Then you have very little power going to provide the resistive heating.

"The neat thing about the way we handle our electrodes is that we suspend them off the bottom of the melt. They are not touching the bottom. When you’re melting a site that has a lot of metal—the metal having a higher density than the molten soil—it drops to the bottom. So you have a pool of molten metal at the bottom. You want the electrodes out of that pool, otherwise you get the short circuit. So we have electrode feeders situated on top of the off-gas containment hoods. These are devices that grip the electrodes and permit us to adjust the electrode insertion depth."

What effect does moisture in the soil have on the melting process? And what is the subsurface moisture content?
"Soil moisture at Taranaki is very low. Less than five percent. Obviously, it’s a desert environment. With moisture, in general, it takes a little more energy (for ISV) because you have to boil off the moisture. For example, some of the projects we’ve done in the U.S. have involved very wet sites. One of the Superfund projects we had in Michigan involved a wet clay site, with groundwater flowing through a sand lens into the area we were trying to vitrify. You can still process that, as long as the recharge rate is low enough so that you are not simply continuing to boil water. You cannot melt the soil until the water has been vaporized."

It’s like trying to sweat copper plumbing with water in the lines. You can’t do it."
“Exactly. So what you have to do with a real wet site that has a high recharge rate is to set up a water diversion trench, or some sort of a pump system, or barriers. You have to have some kind of dewatering approach. We’ve had to do that a few times in our projects. And it works just fine.”

What are the gases that you’re constrained to contain?

“The gases that come off of the melt are largely CO and CO$_2$ and these come from the decomposition of limestone and dolomite. Actually, CO comes out of the melt because CO$_2$ cannot exist in the melt because of the high temperatures. CO bubbles out, and it’s immediately oxidized within the hood to CO$_2$,” Leo explains. “Other gases include air; we draw air into the containment hood. Most of the off-gas is actually air.

“You also have some organic decomposition products that come out of the melt. Because the melt is so hot, you’re usually breaking those organics species down to their basic components,” Leo says.

So venting is no problem?

“No. Handling the off-gases is not a problem. The Australian government and the regulatory agencies are primarily concerned with plutonium emissions. Now, one benefit is that Pu is non-volatile and is stable in the ISV melts as an oxide. It has next to no vapor pressure at 2000°C. Consequently, the Pu mixes thoroughly within the melt, and we get very good retention in the melt.”

Some Geosafe literature states your retention efficiencies were so high that decontamination of equipment wasn’t even necessary.

“That resulted from the two intermediate-scale radioactive demonstrations we did at the site. We processed two kg of U$_3$O$_8$ and the plutonium-contaminated steel plate.

As one of the more toxic things ever known, a half-gram of Pu is a lot.

“Yes, it certainly is. The health physicists examined the inside of the off-gas piping and containment hood and the level of radiological activity very close to background after the test. The conclusion from the health physicists was that decontamination was not required. But we did it anyway. We like to keep the equipment clean.”

You have an “X” pattern for the ISV starter path geometry. How do you start the process?

“First of all, we dig holes in the ground and put the electrodes a foot or two below the surface. Then we dig a little trench between each of the four electrodes. There are, obviously, an array of four electrodes in a square pattern. The diagonal electrodes are connected by trenches forming an “X” pattern.”

How big are these squares?

“The spacing for the electrodes can vary from about 3 m up to 5.5 m. At Maralinga the spacings are going to be from 2 to 5 m. It depends on how big a melt you’re going to make and other operating parameters that you’re trying to achieve. So, say you’ve decided on a spacing of 3.5 m on a side. That’s about 11 feet between the electrodes on the side of the square. The little trenches are just a couple of inches deep and a couple of inches wide, scratched out in the surface soil. We lay a starter path in the trench, and this is a mixture of graphite flake and glass frit. It’s electrically conductive. And when you’re ready, you put an electric potential on the electrodes. The current flows through the path. There is enough resistance that the path becomes red-hot. The glass frit melts. The graphite is helping to conduct the electricity, and the glass frit also conducts as it melts.”

This frit—is it like cullet? Just broken glass?

“It’s more like a powdered glass. Very fine. Once the path is molten, it conducts heat to the surrounding soil and melts it. Then once you have the soil melted, the sodium and potassium in the soil conduct current, and the molten soil becomes your current-carrying media. You just keep applying power, increasing it, and the pathway gets bigger and bigger, eventually it melts the entire surface. And everything melts together until you’ve got a pool of molten soil.”

When you first apply the potential across the starter path, what is the energy that you use?

“It will be low. A couple of hundred kilowatts. Typically we’ll ramp it up over a period of a day, before we’re in the megawatt range.”

What is the limiting factor for the size, or the volume, of the vitrified mass?

“It’s going to be a function of electrode spacing, time,
how fast we insert the electrodes. The geology and soil type. A number of factors influence the melt size and shape. The largest individual melts are on the order of 1000 tonnes, 6 to 7 m deep and 15 m in diameter.”

What tells you that you’ve juiced this thing long enough? How do you know when to stop applying electric potential?

“We usually have an objective in terms of melt depth, based on knowledge of contaminant distribution. We have the four electrodes that we gradually lower into the ground, and the electrodes are used as four independent dipsticks. So we keep inserting them downward as the melt progresses. The electrodes are marked in increments. If we release them and let them sit on the bottom of the melt, we can see how deep we’ve melted into the contaminated soil.”

What are these electrodes like?

“Large-scale electrodes are typically 12 inches (30.5 cm) in diameter and made of graphite. There are standard suppliers to the steel and foundry industries. It’s a fairly common industrial item.”

How do you lower them into the ground?

“By gravity. If there’s no metal at the site then we don’t have this problem of metal pooling at the bottom. We can let them sit on the bottom of the melt. So we always have an accurate assessment of where the bottom is. But at Maralinga, with all the metal at the site, we’ll have to keep the electrodes off the bottom of the melt, and we’ll just periodically lower them. This is done by remote control using the electrode feeders. Each of these feeders has a drive motor and a series of grippers. So we can merely insert the electrodes deeper. But they never penetrate below the bottom of the melt. They can be naturally fed by gravity if you let them go. It’s a simple process to let them descend by gravity.”

How long do you keep applying power?

“Depending on the size of melt we want, we might apply power from four days to ten days for each melt.”

Do you intend to leave the vitrified blocks in place, or dig them up for examination?

“The intent is to leave the blocks where they are, for in-place disposal. That’s one of the beauties of the process. You’re defeating one of the purposes if you have to dig up the blocks. Many times we’ll do some core drilling or some limited excavation, just to confirm melt shape. Certain clients or regulators want that kind of confirmation. If it’s a large melt, it won’t reach ambient temperatures for about a year.”

Then the innermost portion of the melt has completely cooled?

“Right. The center of the entire mass will cool to an ambient level in roughly a year. The mass will solidify fairly rapidly. But it retains heat. You can excavate and even core drill the blocks when they’re fairly hot, but core drilling is usually delayed until the blocks have cooled.”

Leo explains that drilling equipment doesn’t perform well at elevated temperatures.

How long will the project take?

“The schedule is roughly 18 months for design and construction of the plant. That includes getting it out to the site. We’re going to build it in Adelaide, then ship it out by train to the site. The actual melting of the pits will take about a year.”

Leo again mentions uncooperative weather. Heavy rains, though infrequent, can wash out the dirt roads. To get fuel to the site by tanker truck can be very difficult. Heat can become downright oppressive, forcing shorter schedules for occupational health and safety.

“The neat things about our project are the variety of challenges. The heat, the Pu, the logistics. The bugs. I hope your readers will appreciate the challenges we face on this project.”

Do you think that vitrification holds the key for long-term disposal of mixed and nuclear waste?

“I think there’s no question that it does. Many vitrification technologies have advanced to the point where we’re now dealing with the policy aspects more than the technical aspects.

“People think of the ISV technology as very costly, but it isn’t. For many applications it economical.” Leo is enthusiastic. “Compared to other technologies or approaches that require multiple treatment steps, the costs are usually much greater than those of ISV. We’re very economical for complex, difficult-to-treat sites.”

You enjoy this work very much, don’t you?

Leo chortled. “It doesn’t matter what you do. If you enjoy your job, you’ve really got something.”

Write in 842

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Write in 333

Soil & Groundwater Cleanup Dec/Jan 1997 13
Plan to control losses

Liability limitation through insurance policies can provide premium peace of mind.

By Robert S. Wilson

Professional liability insurance—also known as errors and omissions or malpractice insurance—is purchased by environmental consulting firms and other licensed professionals to address business liability risks that arise from rendering professional services. A comprehensive professional liability program offers a variety of benefits, including:
- Protection for you and your firm from serious financial hardship,
- Financial security for your clients,
- Access to projects where insurance is required,
- Practice improvement through loss prevention education and consultation,
- Expert assistance from a “damage control” team if problems arise, and
- General peace of mind.

Basically, a professional liability policy pays for damages you are legally liable to pay as a result of errors or omissions. The policy may also pay for any subsequent pollution damages that arise in the performance of your professional services. These damages can include economic loss and legal expenses.

The insurance company is also obligated to defend you against such claims, even if the allegations ultimately are determined to be false or groundless. See the sidebar, below, for a brief description of project-specific insurance.

Policies are generally written for a term of one year on a “claims-made” or “claims-made and reported” form. These policies cover only those claims made against you and reported to the insurance company during the policy term and any extended reporting period, subject to the “retroactive date” on your policy.

The retroactive date is the date after which the professional activities of your firm are considered to be covered by the policy. This may be the date on which you first purchased and have since

Robert Wilson is CEO of Pro-Form Insurance Services, Aurora, Ontario. He is also President of the Professional Liability Agents Network (PLAN), Silver Spring, Md., an association of insurance brokers that specialize in liability programs for environmental consultants, architects, engineers, accountants and lawyers.

 Protect the project

Contractors or consultants can be named on an insurance policy for a particular job.

By Robert S. Wilson

Project insurance is an alternative that is gaining acceptance in the environmental remediation industry. Most professional liability policies are practice policies that cover one firm’s environmental practice. However, some carriers also offer “project specific” insurance. Project insurance usually provides non-cancelable coverage for a pre-selected number of years for the design and remedial and/or construction period as well as a discovery period after the project is completed. Coverage can begin with the investigation or design, or anytime prior to when remediation or construction begins. It can extend up to five years after the remediation or construction period has ended. Limits are dedicated to the project and cannot be reduced by claims against the firm from other projects. Usually the entire consulting team and, in some cases, the contracting teams are named onto a project policy. These policies are usually written for projects with remediation or construction values of $2 million or more and premiums are based on both the consulting and remedial/construction fees.

Normally, since the client/owner is the major beneficiary of this type of coverage, clients/owners pay the premium for project policies. This is usually negotiated with the prime consultant.

Write in 845
maintained continuous insurance coverage, the inception date of your firm, or some other date offered by your insurer. The company covering you at the time the claim is reported is the one to look to for protection. Do not look for protection from the company covering you at the time of the alleged error.

The amount of coverage provided by a policy depends upon the limits you choose. It is also subject to your payment of the deductible amount for each claim.

There are many factors involved in determining the premium you will be charged for your insurance coverage. These include the limit and deductible you choose, your discipline, and your firm's size, projects, services and clients. Of course, claims history can count a lot, as well as your firm's professional track record and business practices. Keep in mind that, in a sense, clients pay for a portion of the premiums because this is part of your normal overhead. When clients ask for higher limits of coverage for their projects, it is generally accepted that they should pay the additional premium cost.

Today, professional liability insurance is generally available for environmental professionals, under most circumstances. However, firms may have difficulty obtaining coverage for the following reasons:
- Certain practices or project types are considered to be outside an acceptable risk profile by certain underwriters,
- Some firms may have severe claim histories, or
- A firm may have unacceptable business practices or may accept inappropriate client contracts which would cause underwriters to decline the risks.

Certain environmental firms do not to carry professional liability insurance, for a variety of reasons. Some believe they have sufficient financial resources to self-insure. Some erroneously believe their standard casualty policies provide the coverage. Others believe the jobs they perform do not present a sufficient risk to justify paying for insurance. Still others have clients who do not require professional liability insurance.

Selecting a professional liability program

How should a person judge the quality and security of a professional liability insurance carrier? By asking these questions:
- Does the insurance company specialize in environmental

Continues on page 16 →

What is it, and where did it come from?

Someday you may be asked to clean up someone else’s spill.

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

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Insurance, from page 15

consultants’ coverage?
• How long has the insurer been consecutively writing professional liability for design and environmental professionals?
A carrier with a short track record could exit the insurance marketplace quickly, leaving the “insured” firm searching for a new policy at a time when insurance is not as readily available.
• Does the company have claims supervisors who specialize in handling professional liability claims against design and environmental consultants?
• Does the company offer loss prevention programs and other services to help you avoid potential disputes?
It is wise to check the A.M. Best Company ratings of professional liability insurance carriers. The A.M. Best Company is a private firm that analyzes financial data and assigns its ratings to insurance companies. There are also other well known services, such as Moody’s, Standard and Poor’s and, in Canada, the “Trac Report,” that offer insurance company financial ratings.

Policy coverage
The coverage among the major professional liability carriers is similar in most respects. However, there are some differences in definitions and exclusions that can be critical due to the nature of your firm’s work. There are also significant differences between carriers in claims services, claim philosophies and other policyholder services.
One critical factor is the policy’s definition of “claim.” This determines whether and when your policy kicks in and begins providing coverage. Some policies specify that coverage and defense services begin at the first reporting of an “incident” or potential dispute, rather than requiring that an actual “demand” or lawsuit is made. In fact, some firms reward policyholders for providing an “early warning” of a potential claim by not charging for services against the policy limits or deductible until a formal demand is made. Other policies may not provide any services or coverage until a claim is actually filed. So look for the broadest definition of claim available.
Another critical factor, especially if your firm is involved in remedial contracting activities, is whether the policy provides what is called “contractor’s pollution liability,” or CPL. Briefly, CPL provides additional coverage for pollution damages that arise not from professional services, but from on-site contracting activities, such as drilling, excavation or dredging. This type of coverage is usually combined with a professional liability policy, either within the insuring agreement or by endorsement.

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Also look for policy exclusions. Are there any limits on pollution coverage? To what extent? Who can and cannot be listed as an “insured?” What about foreign coverage for overseas projects? Are your “prior acts” covered, and how far back? These are all questions you need to ask.

Limits and deductibles on professional liability policies are available in many different dollar amounts. The size you should carry depends on your risk threshold, what assets you need to protect, what you can afford and what your clients require. More and more project owners, both public and private, are demanding a minimum of $1 million in limits. Factors also affecting this decision include:

- The number and scope of projects covered, including those back to the policy’s retroactive date,
- The risk level of services provided, and
- The frequency and type of subconsultants and subcontractors used. The more subconsultants or subcontractors used, the more exposure to vicarious liability—liability for losses caused by any uninsured or underinsured sub.

Be mindful of multiple claims in a single year. If one claim wipes out your coverage, a second claim could devastate your business. One option is purchasing “split limits.” Such a policy has a per-claim cap and a high aggregate limit in the event of multiple claims in a single policy year.

Regardless of the limits chosen, some risks may not be covered under a professional liability policy. Claims brought after the policy term are not covered. Nor are claims covered that arise from non-professional services. Policy limits can also be eroded by other claims made in the same policy period, and the legal costs of defending claims also reduce limits, except in Canada where a number of policies cover expenses outside the policy limits.

The Broker
Perhaps the most often overlooked—and most important—element of the professional liability insurance package is the insurance broker. Unless you have a claim or attend a loss prevention seminar held by the carrier, you may never meet an employee of the insurance company. Your primary and sometimes sole contact is your broker.

Selecting the right broker is paramount to receiving the best services for your premium dollar. First and foremost, choose a broker who understands your line of work. Your broker must serve as your advocate when dealing with insurers, and how well he or she understands your business will determine how well your interests will be represented. Look for a

Continues on page 37 →

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Mercury falls as temperatures rise

Thermal treatment technology pilot-scale demonstration removes mercury from mixed waste

By Casimir J. Koshinski, J. Brendan McLaughlin and Thomas E. Weyand

Mercury-contaminated mixed wastes and soils at Oak Ridge, Savannah River, Hanford and Rocky Flats are a well-known environmental problem. The solution requires a process that is capable of achieving complete separation of the mercury from such wastes without disturbing the radioactive components, so that resulting mercury-free radioactive waste can be treated by means of conventional technologies. Recognizing this need, the U.S. Department of Energy (DOE) contracted with Mercury Recovery Services, Inc. (MRS) of New Brighton, Pa., to demonstrate the commercially available medium-temperature thermal desorption process to treat mercury-bearing mixed waste.

The MRS Mercury Removal/Recovery Process, developed in conjunction with Pittsburgh Mineral & Environmental Technology, Inc. (PMET), has been used commercially to remove and recover mercury from contaminated soils and industrial wastes, including chlor-alkali wastes and mining/smelter by-product waste streams. The process, illustrated in Figure 1, has, demonstrated more than 99.99 percent mercury removal efficiency from waste streams that contain up to 40 percent mercury, by weight. In a recent project, more than 6,000 tons (5.4 million kg) of mercury-contaminated soil, excavated from sites along natural gas pipelines, was remediated to virtual background concentrations of less than 2 mg/kg of total mercury.

The MRS process produces a high metallic mercury product suitable for triple refining to high-purity metal. The process produces no liquid effluent and the mercury content of the gaseous effluent is normally below detection limits and consistently below the OSHA permissible exposure limit.

The technology consists of first crushing or shredding the contaminated material in order to achieve a preferred agglomerate size and desired surface area-to-volume ratio. The comminuted material is then combined with additives to decompose mercury compounds and eliminate gaseous sulfur and chlorine compounds from the process effluent. The blended material is next heated in a low-volume, low-velocity air stream in two stages. The first stage is a low-temperature stage during which water vapor and volatiles are vaporized without vaporizing significant quantities of mercury. The second stage involves increasing the temperature to 1000 to 1200°F (540 to 650°C) to vaporize mercury from the dry material. Water vapor generated during the first heating stage is exhausted to the atmosphere in gaseous form after passage through a series of columns charged with sulfur-impregnated carbon, which remove mercury and other impurities. Mercury vaporized during the second heating stage is condensed in a tube-in-shell heat exchanger to produce metallic mercury suitable for refining and recycling. Heat exchanger off-gas is then purified using sulfur-impregnated carbon prior to being exhausted to the atmosphere.

The objectives were to use a model sample material to:
• demonstrate the technical and economic feasibility of recovering mercury from low-level mixed waste containing metallic mercury and mercury compounds (HgO, HgS, HgCl₂),

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Casimir J. Koshinski is manager of process development, J. Brendan McLaughlin is a project manager and Thomas E. Weyand is vice-president of technology for Mercury Recovery Services, New Brighton, Pa.

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• demonstrate the effective separation of mercury from the radioactive component that remains in the residual matrix, and
• determine the optimum process conditions required to consistently reduce the residual total mercury content to less than 1 mg/kg while rendering the treated product non-toxic as determined by the Toxic Characteristic Leaching Procedure (TCLP) testing method.

The results reported here were produced under a contract from DOE Morgantown Energy Technology Center (METC). All testing performed with naturally occurring radioactive material (NORM) was carried out under Nuclear Quality Assurance (NQA-1) protocols.

Modeling of DOE waste streams and experimental results
The material that MRS would model through this program was contaminated soil found in the floodplain of the Lower East Fork Poplar Creek (LEFPC), near Oak Ridge, Tenn. The contamination found throughout this area is from the Y-12 plant of DOE’s Oak Ridge facility. Having this material serve as the model base matrix offered several advantages. First, nearly all DOE weapons facilities have, to some degree, soil containing low-level radioactive and mercury contamination. Second, the material was well characterized in numerous reports from studies performed on the contaminated material. Third, the high clay and carbon content are especially challenging to the process, thereby adding a degree of conservatism to the results.

To obtain a sample material similar to the soil and sediment found in the LEFPC floodplain, MRS contracted with a professional geologist to identify areas where a nearly identical soil/sediment matrix could be obtained, and to obtain approximately 12,000 pounds (5500 kg) of material deemed most similar in matrix to that found in the creek flood plain.

A characteristic of the soil found in the selected area was the presence of fine coal particles throughout the soil matrix. While the presence of coal in the LEFPC soils is attributed to discharges from the Y-12 plant, it is believed that the coal in the model soil is the result of runoff from mining operations conducted upstream.

Continues on page 21 ➔
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Write in 089
Mercury, from page 19

from the selected area.

The specific location from which the model soil sample was collected was the floodplain of the Poplar Creek drainage, north of Airport Road, approximately 2.5 miles (4 km) northwest of Oak Ridge. The soil sample was thoroughly blended and three splits of 15 to 20 pounds (6.8 to 9.1 kg) were separated and prepared for soil characterization, TCLP testing, and analysis by Scanning Electron Microscopy (SEM), X-ray diffraction (XRD), size distribution, and optical microscopy. The remainder of the bulk sample was split in two. One of the two splits was divided further into approximately 40-pound (18 kg) batch fractions that were sealed to retain moisture until processed in test work, while the second split was held as a reserve fraction.

The model soil was thoroughly characterized by chemical and mineralogical analysis including radiochemical analysis. Results from quantitative chemical analyses performed on the base material, sample 1577-1, are presented in Figure 4, page 22. All but two items were below limits of detection for TCLP analysis for metals, volatiles, and base neutral acids. Two constituents identified by TCLP testing were barium, 0.92 mg/l, and benzene, 0.05 mg/l, each below

Continues on page 22 →
Mercury, from page 21

regulatory guidelines. Radio-chemical analysis of sample 1577-1 found 1.68 picoCuries per gram (pCi/g) radium 226.

Contaminated soils comparison with those of LEFPC
Data available on soils found within the floodplain of Lower East Fork Poplar Creek that contain mercury and low-level mixed waste contamination was compared to values for model soil. Data on the creek soils was obtained from “Draft - Treatability Study Report for Mercury in East Fork Poplar Creek, Oak Ridge, Tenn.”

A strong similarity was evident between the model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
<th>Result</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash (as-received)</td>
<td>ASTM D3174</td>
<td>94.59</td>
<td>percent</td>
</tr>
<tr>
<td>Cadmium</td>
<td>EPA 6010</td>
<td>5.1</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Calcium</td>
<td>EPA 6010</td>
<td>178</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Carbon, total</td>
<td>ASTM D3176 (Modified)</td>
<td>22,300</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Carbon, total organic</td>
<td>EPA 9060</td>
<td>22,300</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Cerium</td>
<td>EPA 6010</td>
<td>70</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Chloride</td>
<td>EPA 9252</td>
<td>150</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Lead</td>
<td>EPA 6010</td>
<td>10.2</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Mercury</td>
<td>EPA 7470</td>
<td>0.04</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Pyridine</td>
<td>GC/MS scan</td>
<td>&lt;.05</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Silicon</td>
<td>EPA 6010</td>
<td>115,000</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Sulfur, total</td>
<td>ASTM D129</td>
<td>200</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Sulfur, as sulfide</td>
<td>EPA 9030</td>
<td>&lt;1</td>
<td>mg/kg</td>
</tr>
<tr>
<td>Sulfur, as sulfate</td>
<td>EPA 9038</td>
<td>174</td>
<td>mg/kg</td>
</tr>
</tbody>
</table>

Figure 4 - Chemical analyses on base soil material

soil material selected by MRS and the high-mercury soils at Oak Ridge, particularly in textural class, carbon content, and particle size distributions. Differences in bulk density and cation exchange capacity may be the result of the higher moisture content and possible differences in characteristics of the water itself. Since the process performance depends more on thermodynamic than chemical properties, the difference in cation exchange capacity is expected to have little, if any, effect on mercury removal and recovery. Differences in moisture content affect the time required to complete a furnace cycle, but do not affect mercury removal or recovery. After comparison with the Oak Ridge data, the model soil sample selected by MRS was found to be representative of soils at Oak Ridge and suitable for process testing.

NORM
Naturally occurring radioactive material (NORM) used in this program was obtained from an oil production operation in the Southern U.S. It has been found that NORM often occurs as scale deposits along the internal walls of oil extraction piping. The scale forms as NORM and other soluble materials precipitate from

water, found with the oil, when the mixture cools as it is brought to the surface. NORM removed from internal surfaces of oil production tubulars, collected and processed into a fine particulate, provides a homogeneous concentration of the radioisotopes contained within the scale. A gamma spectrum analysis identifies the highest atomic weight isotope of interest as radium 226. This isotope, with a half-life of 1620 years, is a parent isotope of the NORM daughter isotopes from the decay of radium 226.

The regulatory limit for radium 226 concentration is 5 pCi/g. Radiochemical analysis of the base soil found that it already contained NORM with a radium 226 concentration of 1.68 pCi/g. Hence, this natural content was accounted for in the amount of NORM material that could be added to the base soil as a tracer. Moisture and organic content of the soil were considered because the thermal treatment to remove the mercury removes the moisture and any component in the soil volatilized at or below the maximum treatment temperature of 1200°F (650°C).

Blending NORM with base soil material took place at a facility licensed to handle radioisotopes at concentrations higher than the exempt concentration of 5 pCi/g, in compliance with NRC regulations. Before addition of the NORM, the soil was air dried to remove excess moisture and was ground to facilitate uniform blending of the NORM throughout the soil. After blending, the soil was repackaged in sealed plastic bags, placed in two steel drums and shipped to MRS by common carrier.

Mineral additive
The MRS technology incorporates a proprietary mineral additive blended with the feed prior to processing. The additive fulfills many purposes within the process, including aiding the decomposition of stable mercury phases at lower than equilibrium temperatures, conversion of mercury compounds to their elemental state prior to vaporization, retention of chlorine and/or sulfide components as stable mineral phases, and prevention of the release of gaseous chloride and sulfur compounds. This eliminates problems with corrosion and exhaust emissions.

Test program
The base soil material used for process tests contained a specific activity of 4.23 pCi/g radium 226. As in earlier tests, splits of this soil were loaded into process

<table>
<thead>
<tr>
<th>Test ID</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process time (hours)</td>
<td>3.2</td>
<td>2.3</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Process temperature (°F)</td>
<td>1200</td>
<td>1100</td>
<td>1200</td>
<td>1100</td>
</tr>
<tr>
<td>Feed soil-mercury (mg/kg)</td>
<td>3335.5</td>
<td>6913.1</td>
<td>3531.6</td>
<td>3552.5</td>
</tr>
<tr>
<td>Product soil-mercury (mg/kg)</td>
<td>0.44</td>
<td>1.92</td>
<td>1.07</td>
<td>1.45</td>
</tr>
<tr>
<td>Mercury removal (wt%)</td>
<td>99.99</td>
<td>99.98</td>
<td>99.97</td>
<td>99.97</td>
</tr>
</tbody>
</table>

Figure 5 - Base soil process test results
trays and blended with cerium oxide, mercury, mercury oxide, mercury sulfide, mercury chloride, and the proprietary chemical additive. The blended material was then processed for different time periods at 1100 and 1200°F. Results from these tests are presented in Figure 5, page 22.

Prior to the introduction of NORM into the soil matrix, mercury species is possible. Results from analyses of processed soils show that the mercury content added to the feed soils as mercury and mercury compounds in concentrations ranging from 1500 to 7000 mg/kg was reduced to less than 2 mg/kg in all tests.

Pyridine was not detected in product soils. This is an important result because pyridine is often produced upon partial decomposition of coal.

After being removed from the soil, the mercury was recovered by the process gas handling equipment. The mercury contained in the carbon filtration media will eventually be recovered as metallic product, since the spent carbon is processed through the same system that processes the contaminated soil. The difference in recoveries is a temporary economic concern, as all mercury in the filtration media will eventually be recovered in metallic form.

The mass balance for radioisotopes presented in Figure 7, below, shows that the NORM materials added to the soil prior to testing were retained in the processed soil product, separate from the mercury. Wipe tests collected from the system pipework during the program verified that NORM was not carried over to the process gas handling system during this test. Results obtained during this study should be scalable.

<table>
<thead>
<tr>
<th>Material/Location</th>
<th>Mass mercury (grams)</th>
<th>Distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallic Hg (Condenser/Piping)</td>
<td>1898</td>
<td>46.2</td>
</tr>
<tr>
<td>Bypass carbon</td>
<td>1588</td>
<td>38.7</td>
</tr>
<tr>
<td>Condenser carbon</td>
<td>585.7</td>
<td>14.2</td>
</tr>
<tr>
<td>Exhaust air</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Product soil</td>
<td>0.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Samples</td>
<td>35.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Total</td>
<td>4108.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Figure 6 - Test program mercury balance**

the process pipework was disassembled and cleaned, and wipe tests were taken. After processing of the NORM-containing material was completed, the system was again disassembled and cleaned and wipe test sampling was repeated. No significant contamination was found on any of the wipes analyzed.

Sensitivity of the NORM tracer detection level is illustrated by the consistency between the values reported from before and after the tests using NORM, and in many cases, this proximity of results caused the value reported for gross alpha prior to testing to be above that reported after the tests with NORM. In comparison to these results, the average allowable total residual surface contamination, expressed in disintegrations per minute per 100 square centimeters from DOE Order 5400.5 for U-235, the parent isotope of radium 226, and other alpha emitters, is 5000 dpm average/100 cm².

Mass balances were calculated for mercury and NORM to determine the distribution of each material in process products and the equipment, in order to firmly establish the quality of the separation obtained through processing. A mercury mass balance was developed for the entire test program based on the amounts of mercury recovered as metallic product and analyzed contents of processed soils, carbon filtration media, exhaust air, and samples from process feeds, in order to establish the distribution of mercury through the system after processing the contaminated feeds. This balance is summarized in Figure 6, above. The total amount of mercury, 4108.7 grams, equals 100.6 percent of the total amount of mercury added to the system, (4082.5 grams) over the course of the test.

Two of the primary objectives of this project were to demonstrate that the technology can successfully remove and recover mercury from the base model material and that an effective separation of the radiochemical isotope (or surrogate tracer) from the

\*

<table>
<thead>
<tr>
<th>Test</th>
<th>1678-1</th>
<th>Resags</th>
<th>Samples</th>
<th>Net feed</th>
<th>Post process weight</th>
<th>Post sample weight</th>
<th>Loss in weight (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>176</td>
<td>3.9</td>
<td>(2.0)</td>
<td>171.7</td>
<td>152.9 (2.0)</td>
<td>145.2</td>
<td>(2.2) 13.67</td>
</tr>
<tr>
<td>B</td>
<td>216</td>
<td>4.6</td>
<td>(1.5)</td>
<td>172.1</td>
<td>150.6 (2.6)</td>
<td>147.7</td>
<td>(2.7) 11.66</td>
</tr>
<tr>
<td>C</td>
<td>166</td>
<td>3.9</td>
<td>(1.7)</td>
<td>168.2</td>
<td>145.2</td>
<td>147.7</td>
<td>(2.2) 13.67</td>
</tr>
<tr>
<td>D</td>
<td>165</td>
<td>3.9</td>
<td>(1.7)</td>
<td>167.2</td>
<td>147.7</td>
<td>147.7</td>
<td>(2.7) 11.66</td>
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<tr>
<td>Total</td>
<td>676</td>
<td></td>
<td></td>
<td>684.6</td>
<td>596.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Activity in Feed Material = (676 x 453.6 x 4.23) pCi = 1297060.1 pCi

<table>
<thead>
<tr>
<th>Test</th>
<th>Calculation (lbs gCi/pCi g)</th>
<th>Total activity (pCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>159.9 * 453.6 * 4.71</td>
<td>326,664.12</td>
</tr>
<tr>
<td>B</td>
<td>150.6 * 453.6 * 4.88</td>
<td>333,363.34</td>
</tr>
<tr>
<td>C</td>
<td>145.2 * 453.6 * 4.18</td>
<td>272,306.16</td>
</tr>
<tr>
<td>D</td>
<td>147.7 * 453.6 * 4.15</td>
<td>278,036.38</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,213,370.00</td>
</tr>
</tbody>
</table>

Difference in pre- to post-treatment material = 83,690.1 pCi (6.4%)
Fix a course into $N_2$

Nitrogen exchange between land, air and animals makes soil a life-giving substance.

By Alfred R. Conklin, Ph.D.

Plant nutrients play a dual role in the environment. They are essential for plant growth and for the production of a plentiful food supply. Microorganisms that biodegrade organic compounds, including pollutants, also require these same nutrients for maximum activity. A balanced supply of nutrients in soil is essential for plant growth and for the decomposition of organic matter.

On the other hand, these same nutrients, sometimes in plant-unavailable forms, are a source of serious pollution.

Inorganic and organic nitrogen compounds are generally deficient in nature. Nitrogen is an essential nitrogen to other atoms as fixation. Thus, they are concerned about fixed nitrogen. Nitrogen bonded to oxygen or hydrogen to form nitrate or ammonia or ammonium is necessary for it to be available to plants or to be fixed. Organic compounds are fixed but must be broken down into one of these species for the nitrogen to become available to plants.

Of the plant nutrients listed in Figure 3, page 27, nitrogen is the most often lacking in the soil. Thus, it is the plant nutrient most often added and is added in the largest amounts. Nitrogen fertilizer comes in one of three basic forms: nitrate, ammonia, or urea. These are added to soil either as part of a larger molecule or in a mixture with other nutrients. Nitrate is commonly added as ammonium nitrate. Ammonia is also added as a single pure compound such as ammonium or as one of several types of ammonium phosphate. Urea is used in the form of pellets or in a solution with other nutrients.

In nature, nitrogen undergoes many transformations, cycling between gas, ammonia and ammonium compounds, nitrate, nitrite and nitro compounds and a vast array of organic compounds. This cycling is called the nitrogen cycle, see Figure 1, above. The reactions that are part of the nitrogen cycle, mediated by numerous native microorganisms in soil and water, are listed in Figure 2, page 25.

Under aerobic soil conditions organic matter is readily broken down and ammonia (ammonium) released. This is ammonification (step 1). The ammonium in turn is oxidized to nitrite, which is rapidly further oxidized to nitrate. This two-step reaction is called nitrification. Nitrification involves two different microorganisms acting in tandem (steps 2a and 2b). Under anaerobic conditions nitrate is converted to nitrogen gas and several gaseous nitrogen oxides. All of these can be lost from soils and are unavailable to plants. This process is called denitrification. Gaseous nitrogen can be incorporated into plant and microbial tissue by a process called nitrogen fixation. This process is carried out by various free living soil

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microorganisms, blue green algae and by microorganisms in symbioses with plants. This last process is nitrogen fixation by rhizobia in association with leguminous plants and trees. This whole process is continuously occurring in soil.

Nitrates and ammonia (ammonium) are available to plants. Anion exchange capacity, the attraction of soil for negative species, is generally low and thus nitrate, NO₃⁻, can and does move readily in soil. It can leach out of soil and can move significant distances to roots or to sites of high microbial activity. Nitrite produced during the oxidation of ammonia is toxic. However, it is more easily oxidized than nitrate and thus does not normally accumulate in soil.

Nitrogen compounds are rapidly converted to nitrate in soil if the conditions are within certain parameters, such as having available water and aerobic conditions. Soil moisture should be in the potential range of -0.33 and -1 bars. A soil temperature between 4 and 40°C is required for significant nitrifying bacterial activity. Optimum pH is between 6.5 and 8.0. The further outside this range, the slower is nitrification. When soil pH is 4.5 or lower, nitrate production will often stop altogether. A soil moisture level of -0.33 bars, a temperature of 30°C and a pH of 7.0 will provide favorable conditions for high rates of nitrate production.

Nitrate can move through soil to contaminated sites. It can readily be applied with irrigation or leaching water. Subsequently, nitrate can penetrate to zones deep in the soil or that occur between water or fertilizer application zones. In a growing corn crop, fertilizer nitrate applied to the soil surface does not leach out of the soil. It is taken up by the corn plant before it can move out of the rooting zone.

Figure 2 - Nitrogen cycle reactions

\[
\text{organic nitrogen} \rightarrow \text{microbial degradation} \rightarrow \text{NH}_4^+ \text{OH}^- + \text{CO}_2 + \text{H}_2\text{O} + \text{energy}
\]

\[
\text{NH}_4^+ \rightarrow \text{nitrifying bacteria} \rightarrow \text{NO}_3^-
\]

\[
\text{NO}_2^- \rightarrow \text{nitrifying bacteria} \rightarrow \text{NO}_3^-
\]

\[
\text{NO}_3^- \rightarrow \text{denitrifying bacteria} \rightarrow \text{nitrogen oxides} + \text{N}_2
\]

N₂ → nitrogen fixing bacteria and legumes → nitrogen incorporated into biological materials

Continues on page 26 →
Ammonia added to soil immediately reacts with soil water and forms ammonium, $\text{NH}_4^+$ \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_3 \text{OH}^-$. Anhydrous ammonia, ammonia without any water present, in a compressed, liquid state is often used as a fertilizer.

The availability of nitrogen in soil is also related to the soil's carbon content. This is referred to as the carbon to nitrogen ration, or C/N ratio. In soil organic matter the C/N ratio is in the range of 9/1 to 12/1. That is, 9 to 12 carbon atoms for each nitrogen atom. If the C/N ratio is low, less than 9/1, then nitrogen will be released into the soil. If the C/N ratio is greater than 12/1, nitrogen will be tied up in the decomposition process. These ratios are not hard and fast. If the carbon source is resistant to decomposition, then nitrogen may be released even though the C/N ratio is high, and vice versa. High C/N ratio materials may be used to tie up nitrogen. However, eventually this nitrogen will be released into the environment.

To avoid nitrogen pollution, it is better to add small amounts of nitrogen to the organic pollutant to be decomposed. This nitrogen will cycle, used over and over again, until the carbon source is decomposed. In this way we can limit the possibility of nitrogen pollution.

On the negative side, nitrate in soil can easily be leached in groundwater. It can then move into drinking water, lakes, streams and rivers. The application of large amounts of fertilizer or nitrogen containing compounds to soil can thus lead to water pollution. Fertilizers and high nitrogen content compounds must always be handled with caution because of the pollution potential.

There is another very interesting part of the nitrogen cycle, and that is denitrification. Under anaerobic conditions...
conditions, nitrate will be decomposed, releasing nitrogen gas. Denitrification rates are highest at pH’s near 7 and near temperatures of 25°C. At pH’s less than 6, the products of denitrification contain large amounts of nitrogen oxides, N₂O and NO. These are not good if one is trying to clean up the environment. The presence of easily decomposed carbon sources, such as sugars and simple organic acids, enhance denitrification.

Microorganisms take oxygen from nitrate and use it for the decomposition of these compounds. If the soil or water environment can be controlled, denitrification can be used to remove nitrate.

Denitrification also occurs in aerobic soils. Pores in soil may contain anaerobic zones that allow anaerobic processes to occur even though the soil as a whole is aerobic. Soils that are alternately wet and dry contain aerobic zones that allow complex organic compounds to be partially decomposed by aerobic mechanisms. These zones may be anaerobic when the soil is wet and the organic compounds may stimulate rapid denitrification.

Anaerobic decomposition of organic compounds can be beneficial. Some compounds that are hard to decompose under aerobic conditions will decompose, at least to some extent, under anaerobic conditions. Such partially decomposed compounds may be subject to ready decomposition under aerobic conditions. It must be kept in mind that under anaerobic conditions a major byproduct of decomposition is methane. Methane can cause serious safety hazards when in a confined space.

Phosphorus is another plant nutrient of concern. It is an important plant nutrient that is frequently lacking in soil and thus is added as a fertilizer. Phosphate can also cause environmental problems, particularly when it is in high concentrations in water. In soil, phosphate reacts with iron and aluminum to form insoluble and unavailable phosphates. These compounds do not move through soil and thus do not pose an environmental hazard. However, soil erosion can move phosphate-rich materials to water and thus cause environmental damage.

In remediation, soil phosphorus is of less concern than nitrogen.

Nitrogen is an important part of any remediation effort. It may be needed to stimulate microbial degradation. It can also be a pollutant and can move readily in soil. Handled properly, nitrogen can be beneficial without being a potential problem or pollutant.

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Soil & Groundwater Cleanup Dec/Jan 1997 27
Pesticides in Ground Water, by Jack E. Barbash and Elizabeth A. Resek, 1996, Ann Arbor Press. Written not as a teaching tool, but as a reference, this hefty work should answer most questions one may have about plant or bug killers in water beneath our farmland.

Reference and index sections, together running 120 pages, make this a very useful book for understanding the toxicity or migration of any of a hundred common pesticides. An overview has virtually useless EPA data summary maps, but areas of concentration are more evident in the text—coastal areas and the Mississippi Valley receive more chemical applications. For the non-chemist, tables break pesticides down into orderly categories, e.g., carbamates, ureas, amides, amines, and so forth. Ground water, however, should be a single word, as in our magazine name.


Dense Chlorinated Solvents and other DNAPLs in Groundwater, by James F. Pankow and John A. Cherry, 1996, Waterloo Press. Wow. Sometimes a book takes your breath away. If you're interested in DNAPLs, this one does it. This book delivers for readers with virtually all levels of knowledge.

A particularly good differentiation between low absolute solubility and high relative solubility of chlorinated solvents directly relates to the residual compound toxicity that drives remediation in the first place. Graphics are excellent. Text is first-rate. Even the history of DNAPLs is detailed.

Admittedly, the math will be out of the range of many folks, particularly where migration models are discussed. But the strong, authoritative voice carries the entire book. If one truly wants to understand fate and transport of DNAPLs, one should have this volume.


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Write in 140
Environmental Modeling, Fate and Transport of Pollutants in Water, Air, and Soil, by Jerald L. Schnoor, 1996, John Wiley & Sons, Inc. A periodic table with freshwater concentrations for half the entries is an interesting element to this textbook for senior-level or graduate environmental engineers.

Phrases like “with appropriate units” occasionally leave the reader backtracking, but the overall mathematical treatment fits the readership. Most assumptions, critical to simplifying numerical relationships, are spelled out.

The index is poor; it’s as thin as college cafeteria potato soup. Students deserve more help in finding onerous scientific terms. Graphics tend to be clear, but several are clumsy or just plain confusing.

It is an enormous undertaking to explain contaminant migration. This textbook succeeds in that effort, but a lack of attention to details keeps this otherwise excellent treatise in the category of compelling books that do not complete their compensable journey.

Making the grade: Readability: A. Graphics: B. Ethos: A. Pathos: B. Logos: A. GRADE: B+. Suggested readership: Students of fate and transport modeling who have learned the calculus, environmental science instructors who have learned the calculus, and chemistry students who will be sitting on zoning boards in the year 2020.

An Introduction to Soils for Environmental Professionals, by Duane L. Winegardner, 1996, CRC Lewis Publishers. In this case, you get just what the title says. This is not a “how-to” book. There is plenty to learn here for all but the most accomplished soil scientists.

Structure, physics, hysteresis, capillary rise, nitrification (see Dr. Al Conklin, page 24 in this issue), methane, hydrogen bonding, mechanics, compressibility, moisture measurement and good, old-fashioned mineralogy are each detailed in surprisingly good form. The treatment is interesting and informative.

An effective 8-point checklist for interpreting data from outside sources reminds the reader that a lot of science for science’s sake isn’t worth a bucket of dirt. Graphics, simple and effective, employ a level of math between that of an engineer and that of a banker.


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Write in 207
Give diligence its due

Self-incentive auditing laws protect from disclosure and facilitate Brownfield redevelopment

By Julia Lynn Nye, J.D. and Thomas R. Fox, J.D.

Many states offer immunity and limited privileges for a voluntary self-audit. Some state environmental audit laws encourage environmental compliance by providing privilege for audit reports or immunity for violations revealed by audits. Generally, a “privilege” is defined as a particular benefit or advantage enjoyed by a person, company or class, beyond the common advantages of other citizens. This is to be distinguished from “immunity,” which is defined as an exemption, as from performing duties that the law generally requires other citizens to perform. For example, exemption from paying taxes. Many states offer both privilege and immunity for voluntary audits, while others offer only one form of incentive. These environmental audit incentives are particularly useful in connection with Phase I Environmental Site Assessments, Environmental Audits, and other such due diligence investigations, because such activities generate reports and data that may document instances of environmental contamination or non-compliance. With creative application and proper structuring, in states that offer these incentives, these audits can be used to facilitate mergers and acquisitions and to satisfy due diligence investigations. Also, the audits are shielded from discovery by other persons or provide limited immunity from legal action resulting from any violation, if the violation is disclosed appropriately.

The environmental audit laws can also be used to facilitate Brownfield redevelopment. State environmental audit laws allow a participant, in careful circumstances, to protect their investigations and audits performed in connection with their application to and during Brownfield renovation projects and associated state Voluntary Cleanup Programs. This is because only certain data needs to be reported during the Brownfield redevelopment and Voluntary Cleanup Program participation. Data can be prepared as a separate report to be forwarded to the state, while the underlying research and full report are protected in accordance with that state’s self-audit law.

The state audit privilege laws generally extend protection to all documents and communications prepared in connection with an environmental audit, such as the auditor’s report, memoranda and documents analyzing the materials described in the audit report, and a plan to correct and/or prevent non-compliance and improve current compliance.

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Generally, exhibits and appendices containing supporting information collected for the primary purpose of the audit are covered, including, but not limited to:

- interview with current and former employees,
- field notes and records of observations,
- guidance, notes and drafts,
- findings, opinion, suggestions and conclusions,
- legal analyses,
- drawings, photographs, laboratory analyses and other analytical data,
- computer-generated or electronically recorded information, and
- maps, charts, surveys and other communications associated with the audit.

However, information collected by a regulatory agency or pursuant to an environmental or health and safety law, or obtained from a source not involved in the preparation of the audit report, is typically considered to be non-privileged.

The privilege usually bars the use by state agencies and discovery in state courts of audit-related documents. In most states, a person who participated in the preparation of an environmental audit may be required to testify about the physical events surrounding a violation, but not about information related to any privileged part of the report. The requirements for the privilege application vary from state to state, so one should examine the specific laws in their state.

The self-audit privilege does not apply if it has been expressly waived. A disclosure made to certain people associated with the company under a claim of confidentiality or to address a matter raised by the audit will generally not waive the privilege. Obviously, the privilege cannot be used to commit fraud or to cover up a criminal offense. And, the privilege can be lost if audits produce evidence of non-compliance with an environmental law and appropriate efforts to achieve compliance were not promptly initiated and pursued with reasonable diligence.

In states that offer a self-audit immunity law, a company that discloses a violation revealed by a voluntary audit is generally immune from an administrative, civil, or criminal penalty for the violation. One should check their specific state’s law for the prerequisites to receiving immunity in that state.

Typically, there is no immunity granted for disclosing violations committed knowingly; for those committed recklessly and resulting in substantial injury or harm; or, for repeated or continuous violations that a company has not attempted in good faith to correct. In most states, a penalty imposed under these exceptions to the

Continues on page 32 →
immunity should be mitigated by factors such as how voluntary the disclosure, efforts to conduct the audit, cooperation with government officials, or remediation. Finally, the immunity does not apply to violations revealed through routine agency procedures. Self-audits have revealed violations that would have gone undetected by regulators. A company recently informed the Texas Natural Resources Conservation Commission (TNRCC) of 33 violations, which were revealed by its last self-audit, that would not have been otherwise uncovered. To date, the TNRCC has been notified of more than 230 environmental audits and more than 30 violations. More importantly, these laws encourage companies to address and to correct any non-compliance that they find. Critics of audit privilege laws argue that they will make prosecution of environmental violations more difficult. First, the pre-trial litigation may be extended in order to determine whether an audit report is protected and whether the efforts to initiate compliance were pursued promptly and with due diligence. Second, companies may abuse the privilege by instructing auditors to orally report violations to avoid leaving a paper trail. Or, since only the parts of the audit that are related to the issue under consideration are discoverable, companies might ignore any secondary violations. Third, in cases where a company does business in several states, citizens may shop for a forum to file their lawsuits in which no audit privilege laws exist. Fourth, the protection of audit reports may inhibit criminal investigation of environmental violations, since the reports help assess a defendant’s state of mind by offering evidence of what the defendant knew and when.

Finally, the audit privilege laws may weaken the states’ ability to enforce environmental laws. EPA is concerned that it will have to expend federal resources to pursue environmental violations that would have been the state’s responsibility except for state legislative restrictions precluding the state from acting on audit results. However, no claims regarding these anticipated problems have been made, probably in part because these laws have only recently been passed.

In a 1986 policy statement, the EPA acknowledged the
benefits of environmental auditing. It also reserved the right to request an audit report when needed to accomplish a statutory mission or criminal investigation, rejecting an absolute privilege for audit reports. In a 1995 policy statement, the EPA again rejected an absolute federal privilege for audit reports, but it eliminated a component of the gravity-based penalty in cases in which a company promptly discloses and corrects a violation and any resulting harm revealed by an audit, agrees to prevent recurrence of the violation, and fully cooperates with the EPA.

The EPA policy offers little protection against disclosure to federal agencies and merely mitigates punitive damages. Moreover, the policy is only intended to present guidelines for reducing penalties, so that EPA officials may, at their discretion, deviate from the policy. Furthermore, the policy does not apply to information that is required to be reported by law or permit specifications, such as emissions violations detected through required monitoring or violations revealed through required consent order.

State audit privilege laws should be viewed with caution, since the EPA does not recognize a federal audit privilege that is as expansive as those laws. First, EPA enforcement actions almost always involve federal statutes enforced in federal court, where the less expansive federal policy applies. Second, EPA Administrator Carol Browner has warned that self-audit laws may lead the EPA to withdraw its delegation of authority to enforce federal environmental programs. For example, states that seek to maintain their own operating permits for air emissions must have the authority to enforce permit conditions. EPA approval of a state’s air programs hinges in part on the ability to enforce the terms and conditions of such permits.

If your state has not passed a self-audit privilege law, and depending upon the laws of your jurisdiction, there are other common law privileges that generally afford potential protection from having to disclose documents, including Phase I ESA’s and environmental audits, including privileges for:

- attorney-client communications,
- work product exemption,
- critical self-analysis,
- investigation,
- informally consulted expert,
- trade secrets,
- party and witness statements,
- health and safety audits, and
- privilege against self-incrimination.

Many of these privileges are qualified. To be on the safe side, companies should assume at the outset that all the materials generated by an environmental audit or site assessment may be potentially discoverable. The greatest protection from liability based on environmental audit materials is a sound, honest program to address instances of non-compliance as soon as the audit discloses them.

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Precision decision

Data validation for QA/QC samples should meet overall sampling plan objectives so accuracy prevails over precision.

By Douglas M. Chatham

Field duplicates can be eliminated from most environmental projects. Additional sampling locations provide no information about accuracy and questionable information about precision. A much better evaluation of site precision can be obtained by dividing the set of environmental samples into statistical subsets.

For each QC sample or analysis proposed, project managers and Quality Assurance Project Officers (QAPOs) should ask just what contribution to quality these control samples provide. If a QC sample contributes nothing toward the data quality objectives (DQOs), then an argument should be made against incurring their cost.

Splits and co-located samples

A split sample is one that has been thoroughly blended and divided between two containers. Often, the split samples are analyzed by different laboratories. The idea is to measure the precision of the entire sampling and analysis procedure. Splits that contain target compounds are a measure of how thoroughly the original sample was blended before being split.

Samples taken adjacent to one another are termed co-located. These samples are not blended. Co-located samples analyze to measure sampling precision, or the variability of the matrix being sampled.

EPA, in Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A) (December 1989) states: "When designing experiments or procedures, it is important to keep in mind that the overall objective is accuracy. It naturally follows that those in charge of a project should ask whether additional measurements really contribute to the accuracy of a method, or simply to its precision... We all know that precision is important, but we need to take a closer look at the costs and benefits to the customer when expenses are increased for the sake of improving precision without necessarily increasing accuracy."

Often, the stated purpose of field duplicates is to measure the precision of the complete process from sampling through analysis. This is nice-sounding phraseology in a work plan, but what can you do with the results?

The greatest variation in environmental analytical results is the variability of the media. Even with the best efforts of the best sampling technicians available, comparable results are seldom achieved from co-located duplicate soil samples. A statistical evaluation of all sample results at a site should be used to measure the precision and representativeness of the sampling program. These statistical measures may provide confidence intervals for establishing extent of contamination in a medium. To adequately assess sampling precision, duplicates are selected as a subset of the samples taken at the site. Subset results are then compared to overall values from the original samples.

Reduction of matrix spikes

The matrix spiking program should be eliminated from EPA protocols except for projects that can justify the expense of spiking every sample proposed. Surrogate recoveries, sample-by-sample, measure accuracy better. Laboratory control sample/laboratory control sample duplicate (LCS/LCSD) results for each batch, with the laboratory control charts, are the best measure of both accuracy and precision.

Matrix spike (MS) samples are analyzed to determine the effect of the sample matrix on the accuracy of the analytical results. The spike is a known amount of analyte to a normal sample in the lab. Matrix spike duplicates (MSD) are the second pair of lab matrix spike samples, and are analyzed to check the precision of analytical procedures. In order to evaluate the effect of the sample matrix on analytical data, triplicate volume is collected for one sample out of every group of 20. Two portions of the sample (the MS...
and the MSD are spiked with a standard solution. These spiked samples are analyzed, and the percent recovery and relative percent difference are calculated.

**Four key points**
- Use surrogate recoveries to measure matrix effects for organic analyses,
- Use laboratory control spikes/duplicates (LCS/LCSD) rather than MS/MSDs to determine precision and accuracy,
- Use control charts for warning and control limits for precision and accuracy, and
- Avoid MS/MSD for metal analyses; metal analyses do not generally require a measure of matrix effects since the digestion and analytical methods destroy the matrix.

**Factors and variability**
The variability of the sampling process is largely a function of the localized differences in the environmental media. The matrix effect is as variable as each medium and its contaminants. To be truly effective in determining method accuracy and precision, matrix spiking would have to be done for all samples, which would be prohibitively expensive.

Soils vary in their sand, humus and water content; the mineral, electrolyte, pH and the types of natural organic matter vary considerably, even in very localized areas. Even with a batch of samples with similar sand, clay, humus and electrolyte composition, variations in the total amount of contaminants can affect recoveries of specific contaminants. The total amount of petroleum compounds will directly affect recoveries of BTEX.

Data validation guidelines include the following steps if MS/MSD results do not meet criteria: 1. No action is taken on MS/MSD data alone. Decisions based on MS/MSD data must be supported by other types of QC, such as surrogate recoveries, which can stand alone. 2. The data reviewer should determine to what extent the results of the MS/MSD affect the associated data. 3. In those instances where the results of the MS/MSD affect only the sample spiked, then qualification should be limited to this sample alone. However, it may be determined through the MS/MSD results that a laboratory is having a systematic problem that affects all associated samples.

**Accuracy over precision**
The matrix spike sample is analyzed to determine accuracy; the matrix spike duplicate sample is included in a sampling plan to measure analytical precision. The overall objective in the design of sampling for either experiments or field procedures is accuracy. In this there can be no mistake. Project managers must understand that accuracy is the more telling attribute when compared with precision. We all know that precision is important, but the expense of improving precision without necessarily improving accuracy is often a waste of time, talent, and energy.

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broker with a solid track record in dealing with environmental professionals. Ask for references from the broker. Ask your peers for broker recommendations.

Your broker should be qualified to serve as your risk management consultant. Select one who can provide a wide range of services, including loss prevention education for your staff and professional services contract language review and advice. Your broker should also be able to provide you with a choice of carriers and inform you of the pros and cons of each.

Price

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Certainly, when faced with two equal PL programs, go for the lower cost. However, realize that "cost" goes far beyond premium dollars. Consider the full long-term cost of the PL program, including the time, money and client relationships that could be saved if a claim arises. That eventuality, after all, is why you’re buying insurance.

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Big picture

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Contributed Papers and Posters are invited for presentation in the general sessions in the following areas:

- site assessment/field sampling
- environmental fate and modeling
- hydrocarbon identification
- chemical analysis
- soil chemistry
- hazard, exposure, and risk assessment
- regulatory programs and policies
- innovative remedial technologies
- standard remedial technologies/corrective actions
- case studies on any of the above

**SPECIAL SESSIONS**
Presentations for special sessions related to the following areas are encouraged:

- contamination at military installations
- ecological risk assessments
- innovative technologies
- phytoremediation
- chlorinated hydrocarbons, pesticides and heavy metals
- RBCA
- state regulatory programs
- cleanup standard setting
- international work

**Association of American Railroads Sponsored Session on Railroad Cleanups and Issues**

**DEADLINE FOR SUBMISSIONS IS FEBRUARY 10, 1997**

Publication of manuscripts from both platform and poster presentations will be considered for either the general proceedings, to be published as a hard cover book, Journal of Soil Contamination, or Soils and Groundwater Cleanup Magazine.

For Specific Details for Submission Contact Linda Rosen 413-545-2934.
California Environmental Protection Agency  
Department of Toxic Substances Control  
Alternative Technology Division  
400 "P" Street, 4th floor  
P.O. Box 806 ◆ Sacramento, CA ◆ 95812 - 0806 ◆ Phone: 916. 324. 1807 ◆ 916. 327. 4494 fax  

Laboratory Report  
Southern California Laboratory. Hazardous Materials Unit. Telephone 213-620-3376  

Collector's Name: MARK BERSCHEID, STATE OF CALIFORNIA  
SCL NO.: 113991418  
Sample Location: BEHRAM IRANI ENTERPRISES, AGENT FOR BRINECELL, INC.  
176 LOS ALTOS AVE, WALNUT CREEK, CALIFORNIA 94598, PHONE: 510-934-8467  
Date Reported: 05/18/91  

Analytical Procedures Used: SCL 816 FOR ANALYSIS (GC-FID)  
EPA PROCEDURE FOR MOISTURE CONTENT  

### DIESEL ANALYSIS

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### MOISTURE CONTENT

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Sample Preparation: LUCIA YAP  
Analyst: LUCIA YAP  
Supervising Chemist: RUSS CHIN
Solinst Model 660 Drive-Point Profiler®

The Drive-Point Profiler® manufactured by Solinst offers multiple discrete zone sampling in a single drive. The Drive-Point Profiler allows contaminant versus depth profiling, and detailed plume delineation through continuous drive sampling.

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Write in 901
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For a wide variety of fluid and air processing applications in environmental systems, PROLITE polypropylene tubing from NewAge Industries, Willow Grove, Pa., offers an alternative to PTFE. Because the virgin polypropylene copolymer used to produce PROLITE conforms to FDA requirements for food contact surfaces, it is an excellent choice for clean applications in virtually all environmental situations. The lightweight polypropylene tubing offers excellent resistance to chemicals, purity, low moisture absorption, high dielectric strength, low surface friction and resistance to corrosion.

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