IN SITU VITRIFICATION
...HOW IT WORKS

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LIABILITY POLICY
COVER
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WE INVITE YOUR VIEWS...

During the season over 5,000 plants mix gravel, sand and dust with about 50,000 ppm hydrocarbon, heat the mixture and load it on trucks. A typical plant generates from 100 tons to 350 tons of this mixture per hour. The product, of course, is hot-mix asphalt. And it makes up most of the roadways in the U.S.

As far as we know, in spite of its high hydrocarbon content, hot-mix asphalt paving hasn’t yet been found to be a source of soil contamination.

When it’s properly mixed, laid, finished and compacted, hot-mix asphalt provides total encapsulation of its contents. As a finished product, it’s so viscous you must break it apart with hammers, chisels or saws.

But one of problems with asphalt is that it won’t coat aggregate that’s filmed with moisture or clay. When you add clay, or clay-coated-aggregate in an asphalt mixture, the mix will quickly disintegrate on the road. The encapsulation is not successful.

In spite of this problem and others, a few companies have acquired the knowledge and the equipment to successfully dispose of contaminated soil by burning it, then mixing it with hot-mix asphalt, then using the mix for paving material. (See “Paving Firm Decontaminates Soil for Hot Asphalt Use” on page 9 of this issue of Soils.)

Others have been successful in mixing contaminated soil with cold-mix asphalt and using the mixture for paving secondary roads and driveways. (See “Contaminated Soil Recycled in Road Mix” on page 7 of November-December’s Soils.)

Still other are trying, but failing. Working without adequate equipment or knowledge they may be creating problems that can’t be solved without massive clean-up.

We invite your views. Share with our readers your knowledge about this application, other new or interesting methods of remediating contaminated soil, or dealing with problems that it poses.

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In situ vitrification subjects the soil to an electrical heating process that turns the treated area into molten mass. See story page 6.

Cover: Thirteen double-wall fiberglass tanks, manufactured by O/C Tanks, were installed as part of a major expansion program for Go Mart of Gassaway, W.V. The two tanks were installed near one of Go-Mart’s new truckstops in southeastern Ohio.
An area treated with *in situ* vitrification is turned into molten mass by an electrical heating process. During the process, organic contaminants are destroyed or captured for off-gas treatment, and inorganics—such as metals—become trapped in the melt. When melted soil completely cools (about a year later), it resembles a monolithic lump of obsidian that weighs 500-1,000 tons.

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**In situ vitrification**

*Melting process turns contaminated soil into glass-like substance*

*By Ron Koehler*

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An award-winning, in-place hazardous waste treatment process that melts contaminated soil in place and turns it into a glass-like substance is gaining recognition as the preferred treatment alternative at a number of sites in the U.S. Developed in the 1980s by researchers at Battelle Memorial Institute’s Pacific Northwest Laboratories (PNL) in Richland, Wash., *in situ* vitrification (ISV) is now under contract to be used at a site contaminated with PCBs in Washington and at a site contaminated with pesticides and mercury in Michigan. The process has also been selected as the preferred remedy at nine other sites, according to Jim Hansen, director of sales and marketing at Geosafe Corp. in Kirkland, Wash. Geosafe was organized by Battelle in 1988 for commercial development of the ISV process, which was patented by the U.S. Department of Energy and licensed to Battelle.

Hansen says one of the big advantages of ISV as a treatment technology is that it can be used to simultaneously process mixtures of...
An abstract of the *in situ* vitrification test site at Battelle Pacific Northwest Laboratories.

Organic, inorganic, and radioactive contaminants in all kinds of soils. Its versatility makes it a strong contender at sites that are considered difficult to remedy.

The process was selected as one of the Engineering Achievements of the Year in 1986 by the National Association of Professional Engineers.

**How it works**

ISV destroys, removes or permanently traps hazardous substances by subjecting the soil to an electrical heating process that turns the treated area into a molten mass. During the process, organic contaminants are destroyed or are captured for off-gas treatment, and inorganics—such as metals—become trapped in the melt. When the melted soil from a single setting finally cools (about a year later), it resembles a monolithic lump of obsidian that weighs 500-1,000 tons. Based on studies of obsidian, a natural glass produced by volcanoes, scientists at PNL estimate that the glass-like lumps will remain stable for millions of years.

Geosafe, in its commercial applications, uses the ISV technology developed by Battelle over a period of eight years at a cost of more than $14 million with funding from the Department of Energy. All of the processing and monitoring equipment, except for a 55-foot-square gas collecting hood, is contained in three mobile trailers. Electric power is obtained from 12.5 or 13.8 kV utility power lines and is transformed to 4,000 volts or less in one of the trailers. If power lines are not convenient to the site, or if a feeder line cannot be built, electrical power can be produced with a diesel generator.

To start the process, four graphite-covered molybdenum electrodes, each about a foot in diameter and 15 to 40 feet long, are positioned to form a square or rectangle with sides 25 to 30 feet long. The electrodes may be buried, or they may be held upright by fittings on the collector hood. Because unmelted soil is not a good conductor of electricity, a mixture of flaked graphite and glass frit is placed between the electrodes to create a conductive starter path for 4,000 volts of electricity applied at 400 amps. When the soil reaches its melting point of about 1,400°C, it becomes conductive, allowing the process to continue with lower voltages and higher amps. As the soil melts—eventually reaching temperatures between 1,600 and 2,000°C—the electrodes sink into the melt zone until they reach a depth of 10 to 30 feet, depending on the depth of processing at the site. Due to the tendency of the melt zone to grow outward, the size of the melted area will be about 50 percent larger than the spacing of the electrodes.

During the melting process most of the organic contaminants in the soil are destroyed by pyrolysis, but

*Continues on page 32*
Above: Inside Continental's soil incinerator. The unit, lined with ceramic blocks, flashes off moisture and hydrocarbons with a 2,000°F flame.
Right: Before and after, At right: untreated soil with up to 30,000 ppm hydrocarbon content. At left: Thermally treated soil ready for incorporation into hot mix.
Paving firm ‘burns dirt’ for hot mix asphalt use

Special kiln flashes off hydrocarbons before production process

By William E. Neeley

Asphalt paving can be a varying mixture of liquid asphalt, sand, gravel, various emulsions, lime, rubber and—in this case—hydrocarbon contaminated soil.

In fact, remediated contaminated soil makes up as much as ten percent of the hot mix asphalt mixtures generated by Continental Paving, Inc., a Londonderry, N.H. asphalt paving producer and road construction company.

The firm has adapted its asphalt production facility to remediate hydrocarbon contaminated soil by fitting a kiln (traditionally used to heat and mix liquid asphalt, sand and gravel) with an additional ceramic lined kiln used only to flash off hydrocarbon and moisture from contaminated soil. Ray Czarnecki, of Continental, explains the process:

“We modified the asphalt plant by adding a ceramic cylinder between the burner and the dryer. The burner and dryer are standard components used to produce hot mix asphalt.

“The ceramic cylinder, about seven feet long by six feet in diameter, operates independently of the dryer. The dryer rotates at about six rpm, while the ceramic cylinder can be adjusted to rotate at anywhere form one to six rpm. This permits control of the hold-up or residence time of the soil inside the cylinder.

“When the soil is dropped into the cylinder it immediately flashes off water and hydrocarbon. By the time it reaches the end of the cylinder, the soil has been heated to about 800°F. At that point it moves into the main drum, and is mixed with other aggregate and liquid asphalt, and is processed into a hot-mix asphalt product.”

According to Czarnecki, the burner flame that heats the special incinerator and drum mixer is about 16 feet long. “The flame moves about 800 feet per minute. Hydrocarbon contaminated soil is held within the flame about .02 minutes, or 1.2 seconds. Most experts agree that you can destroy even PCBs by holding them at 1,500 to 2,000°F, for about one-half second. We move more than double that exposure, and results have shown the process works very well.”

The contaminated soil is metered into the cylinder from a holding bin, via a feeder belt which proportions the soil according to the

Continues on page 10→

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Paving firm 'burns dirt,' from page 9

amount of aggregate being used and according to the production rate of the plant. Rows of oversize ceramic bricks inside the decon- tamination chamber lift the dirt and roll it along the sides of the chamber. The vaporized hydrocarbon actually feeds the flame (fuel requirements are less when using the special incinerator than when simply producing standard paving material).

In the meantime, aggregate and old asphalt pavement (that has been removed from roads and crushed for reuse), is fed into the main drum below the special incinerator. All the materials that complete the paving mixture (including the recycled soil) are combined and mixed in the main drum. The hot mix asphalt is conveyed from the main drum to overhead storage silos for truck loading. Continental produces up to 2,000 tons of hot mix asphalt daily.

“We find that the gradation of the final product meets the original design specification. It doesn’t degrade the product at all,” Czarnecki says.

Off gas generated by the process is pulled through a 51,000 ACMF baghouse for removal of particulate matter from the airstream.

Continental holds incoming contaminated soil on special concrete pads with sidewalls to isolate it from the environment. Because of the high water table in the company’s geographical area, incoming soil is extremely wet, with a moisture content of 18 to 21 percent. The contractor then runs the dirt through a screen which dewaterizes it and eliminates chunks over two inches in diameter. After screening, the soil is stored in a building.

The contractor charges a per-ton fee for thermal treatment and disposal, depending upon the type of soil and contamination. All soil that it accepts goes into hot mix. It does not incorporate soil into other asphalt mixes or return it to the customer after it is treated.

Continental does most of its soil remediation work for oil companies, treating soil to remove gasoline or fuel oil. The contractor does not treat soil saturated with heavy oil or hazardous waste. Mark Charbonneau, vice president of Continental in charge of environmental operations, says that most soil comes from service stations with leaking underground storage tanks or pipelines that must be replaced. The contractor has treated as much as 2,500 tons and as little as 50 tons per site.

“We make it a policy to go and look at all sites that are being brought into our plant. We want to be sure that they’re clear of debris. We want nothing in it but soil,” Czarnecki says. “And we can’t handle high concentrations of clay, no more than about 30 percent. First, the clay doesn’t feed well into our process. Clay also retards hydrocarbons. It’s difficult to remove. And finally, clay makes a poor aggregate (for use in hot mix asphalt).”

Czarnecki says before accepting soil, Continental insists on a complete soil analysis. This provides not only information about the type and level of hydrocarbon contamination, but indicates the flashpoint of the product, its acidity, sulfide, cyanide, toxic metal, and chlorinated material content etc.

“We have a limit of 30,000 ppm (or three percent) of hydrocarbon in the soil,” Czarnecki says. “And that’s very high (for us). That’s extremely saturated. Usually the material we get in is about 5,000 to 7,000 ppm.

Continental’s experience indicates that the average amount of cleanup per site is far greater than many have anticipated. Continental is averaging about 1,000 tons per site. According to the EPA, of the two million underground storage tanks registered, about 500,000 of them are leaking. If each leaking tanks generates 1,000 tons of contaminated soil, and contractors charge from $80 to $150 per ton to remediate it, the total price tag could surpass $40 billion.”

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- Technology Screening
- Potential Problem Screening
- Technology vs. Costs Ranking
- Regulatory Screening
- Investigation Planning
- Cleanup Criteria

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APPENDICES
- Detailed Remediation Descriptions
- Regulatory Status
- References

THIS 300 PAGE manual describes 14 in situ and ex situ remedial technologies for petroleum contaminated soils and provides guidelines for selecting the best method for site-specific conditions.

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Tank owners pay the piper

Owners, not manufacturers, responsible for certification of leak detection equipment

By Darcy V. Case

Tank owners and operators, not the manufacturers, will take responsibility for leak detection equipment that doesn’t meet Environmental Protection Agency (EPA) requirements.

“The responsibility for compliance falls with the owners and operators,” says Mike Scoggins of the EPA’s Office of Underground Storage Tanks (USTs) in Dallas, Texas. “They are responsible for choosing a method of leak detection that meets the performance standards.”

The EPA’s deadline for third-party certification of all leak detection equipment on USTs was Dec. 22, 1990. A tank owner can be fined up to $10,000 a day for each tank in violation, according to the EPA.

“The intent of our rules was not to put anyone out of business unless they shouldn’t be in business in the first place,” Scoggins says. “There were some ‘fly by nighters’ that came into the industry with outrageous claims. These performance requirements will eliminate the people with faulty equipment.”

Jerry Flora of the Midwest Research Institute (MRI) in Kansas
The Midwest Research Institute's facility in Kansas City, Mo., which conducts third-party evaluation of tank testing methods.

City, Mo., which is currently conducting third-party evaluation of volumetric tank tightness testing and automatic tank gauging methods, says that some equipment manufacturers probably will go out of business.

"If there is somebody out there that has equipment that doesn't work, then they will get weeded out, and if it (the equipment) just isn't good enough, they'll make engineering changes and upgrades," Flora says. "Some people might go out of business because they don't want to spend the money to improve their equipment."

The testing equipment manufacturers are not required by law to certify their equipment, but the devices should not be installed or used on USTs unless they are certified, Flora says.

"The deadline as it applies to the manufacturer is that customers won't purchase the equipment anymore unless it has been proven to meet EPA performance standards," Flora says.

Because there are not many third party certifiers in the U.S. (see sidebar this page), often companies have to travel thousands of miles to have their equipment certified.

Transporting the equipment should not be a problem for most testing companies as it is designed for extensive travel, Flora says. "But it does tie up a piece of their equipment for two to three weeks as it goes through extensive testing."

There are seven EPA-approved protocols for the different types of leak detection equipment. After the equipment has been tested, for example at the experimental tank facility at MRI (see Figure 1), the results are given to the manufacturer or distributor and thus given to tank owners that use that specific method.

Tank owners should receive a standard two-page form (a different one for each protocol) detailing the testing equipment's performance and verifying the equipment.

USTest of Lafayette, La., a manufacturer of leak detection equipment, recently hauled their equipment to MRI for certification.

Steven Rountree of USTest says the EPA's rules will encourage "better equipment and fewer leaks" in the future.

Scoggins agreed: "Tank owners and operators in the long run will probably be better off because of the rules. It's a pay now or pay later scenario."

Write in 324 for more information.
Meeting the oil jobber's needs

Service station remediation complex

By Edward Maxwell, Ph.D.

The deep pocket days of service station remediation are over: the major oil companies have spent their money and protected their images. The remaining service station clean-ups are complex.

Today, the needs of the oil jobber must be met. Since two out of three major oil company stations are owned and operated by independent business people (the jobber) or "commissioned agents", the financial burden is on third party operators and not large oil companies. Because these companies do not have the same resources, service station soil cleanup should be looked at in new ways by legislators and remediators.

Jobbers usually contract to buy gasoline from major suppliers or on the "spot market" and then resell it to their own lessees or supply it to their own retail outlets that they either own or lease from a realty company (or other land owner).

While retail outlets are a small factor in the total asset base of a major oil company, retail outlets are the major asset base of a jobber and may represent the total cash stream of a dealer.

The concern of the major oil company regarding remediation is downstream liability (where will the dirt turn up 20 years from now?); the concern of the dealers or independent jobbers is whether or not they can stay in business with the cash flow interruption.

Impact of remediation

The impact of remediation upon an oil company can be quantified. For the jobber, though, the higher the ratio of the retail outlet's cash flow to the total needs of the business, the greater the impact of remediation.

For instance, the dealer, who's total income comes from the cash flow of the retail outlet, can be said to have a 100 percent negative impact on his cash flow during remediation. If the dealer has repair business and the repair business can be kept going, then the economic impact would be the percentage of relationship of the income from gas sales to repairs.

Perhaps an "economic impact factor" assigned to each remediation job by remediators and regulators could be used to determine the course of remediation at the service station locations.

Other than the economic impact on the dealer or jobber, legislators should consider the liability impact on all involved in the remediation and consumer impact for the major oil company.

The "liability impact factor" refers to a numerical value for the long term liability impact that remediation possesses. For example, a contract dealer for a major oil company could have zero cash flow if his station is shut down for remediation. However, if he is old, has no heirs, and his land is owned by a third party, he has virtually no exposure in terms of liability. This is especially the case now since financial responsibility is still being debated. (A dealer who has no liability exposure and who risks zero cash flow if the station is shut down might be more likely to ignore a

Continues on page 16

Edward Maxwell is president of Eastern States Associates, Inc., a manufacturer's representative in E. Norwalk, Conn.
Thermal Destruction of Petroleum Contaminated Soils

The Resource Recovery companies own and operate a Rotary Refractory Kiln which has been specifically designed for the thermal destruction of petroleum products from contaminated soil. Located in Central Florida, the kiln has the technical capabilities to meet or exceed Clean Fill Standards. Soil exit temperatures range from 600°F to 1400°F, dwell time is in excess of 16 minutes, and soils are decontaminated to < 5PPM.

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International Recovery Corp. Companies

“The environmental group that does the work”
Major oil vs. jobbers, from page 14.

leak and attempt minimal effort at cleanup.)

A large independent, like Getty Petroleum Corp., with over 2,000 branded outlets and dependent almost entirely on the cash flow generated by the sale of gasoline at these outlets, with no refining or crude production capabilities and no diversified business interests, would have very high liability exposure and negative cash flow impact. Because of this, different consideration should be given to such large independents.

The more image conscious an oil company is, or the more visible the retail outlet is, the more important it is for it to present a pristine image to its customers. Furthermore, the large independent may be flying the flag of the major oil company rather than his own flag. Therefore, a large independent flying a major oil company flag, with a large asset base in real estate and other investments, may have a moderate impact on cash flow, a low negative customer response to service station downtime for remediation and yet a high liability exposure.

Levels of contamination

Service station contamination fall into several categories. Three general levels are: excavation hole contamination, site contamination and area contamination.

Excavation hole contamination is limited to the boundaries of the tank hole, possibly because it was a recent spill or because the surrounding soil is highly impermeable. This would involve 200 to 500 yards of soil.

Site contamination is limited to the boundaries of the property and could involve thousands of yards of contaminated soil; area contamination is unlimited in scope and, in general, is not covered by this article.

If the contamination is limited to the excavation area and if the tanks and/or piping are not in compliance and must be replaced, this soil must be removed. After it is removed, then it may be aerated or vented on site, off site; or the soil may be recycled in some way.

This is where our impact factors come into play in the decision: If the retail outlet is franchise-operated and the franchisee has no other source of income, then the primary motivating force by regulators and remediators should be to get the company back into business, especially if it has shown due diligence in record keeping and inventory records are accurate and up to date.

Due diligence is not something to be undervalued. Many of the problems in remediation are the result of a lack of due diligence on the part of the dealer or franchisee with the jobber and the major oil company paying for the cleanup because of their high consumer recognition and deep pockets. The importance of the dealer’s cash flow in the total evaluation picture is inversely proportional to the due diligence exercised by the dealer. If it can be demonstrated by the regulators that the dealer has not exercised due diligence, then the fact that there will be a negative impact on his income by remediation must be discounted.

Remediation choices

Remediation techniques should be specifically chosen for practicality in service station applications. Briefly:

1. Removal of soil to a landfill, along with aeration treatment at a landfill. This option is slowly being eliminated since landfills are running out and the costs of trucking to a landfill are high. This method is viable primarily when the desire to reduce station downtime is very important and future liability exposure is not a consideration. Removal of soil to a landfill, except for small amounts of soil with very low levels of contamination, should not be considered.

2. On site, above ground soil venting, aeration or bioremediation. This method is effective at rural locations with a low customer impact because the potential for customer loss is increased when several hundred yards of soil sit on the property. This may be the most economic course for anyone who has tremendous customer loyalty and the available land to allow for this method. Obviously, if the contamination level involves more than a few hundred yards of soil, the use of the property as a remediation site becomes less viable.

If the total property site must be used for business, speed in remediation is essential. Therefore, aeration and bioremediation may not be the best alternatives. However, soil venting has not been getting the acceptance it deserves because of the fear of air pollution. Soil venting techniques need to be developed that work quickly and can operate within air quality requirements.

3. In ground soilventing or bioremediation. This, of course, presents a problem because regulators want to get the contaminated soil out of the ground. If the underground system is non-corrosion protected and has to be replaced, then the contaminated soil must be removed and replaced with the equipment manufacturers’ approved gravel or washed sand.

If the area around the excavation is contaminated, then in situ soil venting or bioremediation is an alternative.

4. Recycling. Recycling in conjunction with in situ soilventing presents the most interesting alternative to quick and effective service station remediation. Use of hydrocarbon contaminated soil in the hot mix asphalt production process and in situ soil venting for the contaminated soil around the excavation area solves a lot of problems and has a positive effect on the impact factors: liability factors are virtually eliminated because hot mix asphalt recycling changes the characteristics of the soil and therefore cannot be traceable to the source; the negative cash flow effect of station downtime is significantly reduced because the soil can be immediately removed and replaced with non-contaminated soil; downtime for the station can be kept within 15 to 30 days; testing of
customer loyalty is reduced because no soil is left sitting on the property and the visibility of in situ soil venting can be kept to a minimum.

Removal of contaminated soil and recycling through a hot asphalt plant can be done for about $150 per yard (about the same as taking it to a landfill) but the liability factor is eliminated and there is no future potential damage to the environment.

In situ soil venting can be done for approximately $30 a yard (depending on the level of soil contamination) and therefore is an inexpensive solution for the thousand or so yards of soil that is outside of the excavation area that may need remediation.

Opinion and bottom line

Every state, local and municipal governing body must begin looking at regional service stations all over again. The dealer or small jobber who finds a leak will be forced out of business because of fines and cleanup costs. The large independent will have to schedule cleanups based on cash-flow projections. Neither situation is healthy for the local water supplies.

Several things need to happen to help bring the smaller gasoline marketers willingly into compliance with the least economic impact.

1. The exercise of due diligence by the service station dealer, landlord and supplier must be determined by local or state authorities. Legal precedent has been set for this: The May 29, 1991, Wall Street Journal reported an Atlanta, Ga., case in which a creditor with the ability to influence on-site hazardous waste disposal decisions could be held liable if contamination occurs as a result of improper procedure. Therefore, the courts are telling us that due diligence is everyone’s responsibility, not just the dealer’s or jobber’s.

2. Implementation of across the board financial responsibility. The problem of financial responsibility for site cleanup is just surfacing as a problem. Major oil companies are self insured. Independents, jobbers and dealers are not. They need pollution liability insurance from insurance companies.

The insurance companies don’t want to insure jobbers and independents because they end up a “deep pocket” with no image to protect. “Insurance companies are also worried that even if they write specific limits into environmental policies, the courts, attracted by the insureres deep pockets, will still make them pay,” (Insight Magazine, August 13, 1990, P. 41).

3. State, county and city involvement in the problem. Currently, very few communities are involved in service station soil contamination problems. State, local and municipal involvement will become essential during the next decade.

The Suffolk County New York Water Authority (SCWA) can provide a model for municipal involvement. They recognize that they’re in the business to sell water and that they owe it to their customers to protect their water supply.

Due diligence for SCWA involves installing barriers to protect water supply and doing soil assessment of whole geographical areas to determine potential danger.

Instead of terrorizing dealers and independents with large fines, municipalities should present positive incentives for due diligence. If insurance companies won’t insure dealers, and banks won’t loan to them, the taxpayer will end up paying for cleanup anyway. Faced with a $250,000 fine, the dealer, with no asset base to protect, will walk away from the problem and go out of business.

The bottom line: service station contamination is now a community issue. There are thousands of small businesses that market gasoline in every state in the U.S. Society needs to make it palatable for them to comply by giving amnesty from fines and assessing them now for future cleanup.

Write in 325 for more information.
Air movement critical in venting

Stand alone soil vapor extraction neutralizes CCl₄, CHCl₃ and BTEX

By Ron Koehler

Soil vapor extraction (SVE) is becoming a popular technology for removing volatile, and in some cases, semi-volatile organic compounds from contaminated soil. Researchers are hoping that scientific understanding will eventually catch up with all commercial applications of the process.

Also known as soil venting, SVE is a conceptionally simple technology that essentially sucks volatile contaminant from the soil with a vacuum blower connected to a network of pipes sealed in bore holes. At sites where the water table is near the surface of the ground, SVE can alternatively be applied by installing the collection pipes in trenches.

Several researchers have pointed out that (dependent on the extent of the contamination and the site specific clean-up standards) SVE can be used as a stand-alone remediation method, or it can be used in conjunction with other technologies such as bioremediation, free

Vapor extraction well

Above: A project engineer for Vapex, Canton, Mass., uses an organic vapor analyzer to measure VOC levels in the discharge from a catalytic incinerator.

Right: A soil vapor extraction system utilizing a rotary, positive displacement vacuum blower, connected to a network of 12 wells.

product recovery, or groundwater pump and treat. Field studies have shown that it can be applied on most soil types, especially sandy soils. But there is some doubt about its effectiveness in heavy clay soils or in similar situations where air movement is severely restricted.

In Waverly, Neb., SVE is being used in conjunction with ground-
water pumping and stripping to clean up a former Commodity Credit Corp. (part of the U.S. Department of Agriculture) grain storage site that was contaminated with carbon tetrachloride and chloroform. The contamination at Waverly, a small community about 10 miles northeast of Lincoln, occurred between 1955 and 1965 when a grain fumigant that contained carbon tetrachloride was used at the storage facility. The contamination was discovered in the city's drinking water in 1982, and further tests led to discovery of the contaminant source and eventual designation of the site as an EPA Superfund site. The vacuum extraction and air stripping (water aeration) systems were put into operation in January 1988.

Gene Gunn, EPA's remedial project manager at the Waverly site, explained that the carbon tetrachloride and chloroform in the soil at Waverly was not in itself a health threat, but it was a definite threat to the city's water supply. "It was determined to be a continuous source of groundwater.

Continues on page 20→
contamination," Gunn says.

The vapor extraction system used at Waverly consists of a vacuum blower connected to a network of 11 wells. Since the level of contaminants in the soil was found to be very low, the extracted vapors were exhausted into the atmosphere without treatment. In most cases, however, vapors extracted from soil during the SVE process must be treated to ensure that unacceptable levels of contaminants are not discharged to the atmosphere.

Field studies at the Waverly site reveal that vapor extraction has effectively removed most of the volatile contaminants from the soil, but the system will be kept in operation until the EPA is satisfied that the site has achieved specified clean up levels.

Other applications of SVE have been performed by Vapex Environmental Technologies, Inc., Canton, Mass., one of the companies that has developed the technology for commercial use. Mike Marley, director of research and development at Vapex, says that one of the most common applications of SVE is for the removal of gasoline contamination.

"With a properly designed system, you can achieve 100 percent removal of gasoline with SVE," Marley says. "If you can direct air to the volatile contaminants, they will be remediated to very low levels—less than one part per million is commonly achievable."

As an example of the effectiveness of SVE, Marley reviewed the results obtained at a site remediated by Vapex in Connecticut. "It was dripping with gasoline (greater than 2,000 ppm of gasoline hydrocarbons)," he says, "and after three months of SVE application, the sample test (on soil levels of BTEX) came back 'non-detectable.'"

He also pointed out that commercial development of the SVE technology began only about five years ago, so much is yet to be learned about it. As part of that effort toward better understanding of SVE, a team of Vapex researchers has been working on the development of numerical models that can help make the technology more successful and cost effective.

A better understanding of SVE and some of the soil conditions that affect it was the goal of a Shell Oil Co. study initiated in 1987 at a gasoline-contaminated site in Costa Mesa, Calif. The researchers who reported on that study concluded that care must be taken to apply soil venting in situations only where it is the most efficient and cost effective option. They also cautioned that not all sites can be remediated in less than three to six months "as implied by many of the cases."

The amount of time required for SVE to remediate any particular site depends on several factors, including the amount of contamination and the type of soil.

David Green, the Midwest operations manager for Griffin Remediation Services, Crown Point, Ind., says SVE treatment can take from one to two years.

Green also reports Griffin Remediation has had good results

Continues on page 33→
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Write in 026 on inquiry card
Insurance coverage—
Liability policies may cover contamination...but watch out

By Scott Forland

Insurance coverage for cleanup may be available under comprehensive general liability (CGL) policies, but determining exactly what kinds of damages these policies cover, and who is covered by them, is not always a simple matter.

Standard CGL policies are all risk policies indemnifying against a variety of events that cause property damage. Prior to 1966, these policies insured against damage caused only by “accidents.” In 1966, CGL policies changed to cover “occurrences,” a broader term consistently interpreted by courts to include indemnity for pollution, including gradual pollution. CGL policies changed again in 1973 to cover “damages” because of property damage caused by an “occurrence.” While both “property damage” and “occurrence” are defined in the standard policy, “damages” is not defined.

Coverage provisions

Coverage for pollution damage under CGL policies generally depends upon whether (1) the escape, release, or discharge of contaminants constitutes “property damage,” (2) when the damage occurred, and (3) whether cleanup costs are “damages.”

Determining the time when property damage occurred is critical to which insurance policy(ies) apply. Under the standard CGL “occurrence” policy, the property damage must occur during the policy period as a prerequisite to coverage. Beginning in 1986, a standard CGL “claims made” policy became available, which protects only against claims made during the policy term, regardless of when the acts giving rise to that claim occurred.

Frequently, no single event caused the damage, and damages are likely to have progressed through more than one policy period before becoming evident. The courts have developed three different approaches to determining coverage responsibility:

• The “exposure” theory—liability is apportioned between insurers providing coverage from the time of the initial exposure to the time the damages become evident;
• The “manifestation” theory—only those insurance companies that provide coverage at the time the damages become evident are liable for property damage; and
• The “injury in fact” theory—an insured must prove the existence of real but undiscovered damages, proved in retrospect to have existed at the relevant time, to establish coverage, irrespective of the time the damages were discovered.

The CGL policies do not define the term “damages,” but if damages are awarded to third parties in a civil lawsuit not involving the govern-
ment, those monies almost certainly would be covered as "damages" under the standard CGL policy.

This is not the case, however, in suits seeking reimbursement of money paid to clean up contamination as a result of a governmental request or order. Insurance companies often defend by claiming such payments are not "damages" as the term historically has been defined by the courts.

Courts have traditionally held that restitutioary relief, such as reimbursement or governmental cleanup costs, does not fall within the scope of coverage for "damages" under CGL policies, but courts across the country differ on this issue.

Exclusion provisions

Two relevant exclusion provisions under standard CGL policies exist—the property-owned exclusion and pollution exclusion.

The property-owned exclusion rejects coverage for property damage to property owned, occupied by, rented to, used by, or in the care, custody, or control of the insured. This avoids the situation where an insured controls the property and might have less incentive to take precautions to prevent damage because of the existence of insurance.

The courts are divided on the issue of whether or not contamination of groundwater under the property is included under the property-owned exclusion. Another issue centers on whether the costs of cleanup on property owned by the insured are excluded. Some leading cases have rejected the contention that coverage is excluded for remedies performed on land in the control of the insured because such work is often performed to prevent damage to third parties that would occur if the preventative work were not done. Of course, to the extent that remedial measures are designed to remedy damage to the insured property, the insured's property insurance policies might provide coverage.

In 1973, the standard CBL policy was revised to include an exclusion for pollution, unless that pollution was "sudden and accidental."

Since 1986, the pollution exclusion provision excludes property damage arising out of actual, alleged, or threatened discharge, dispersal, release, or escape of pollutants. The provision also excludes from coverage any loss, costs, or expenses arising out of any governmental direction or request to test for, monitor, clean up, remove, contain, treat, detoxify, or neutralize pollutants. This fairly new exclusion also excludes contamination caused by a sudden and accidental event. Coverage under this pollution exclusion may prove difficult to obtain.

Duty to defend

Under the standard CGL policy, the insurance company is required to defend any suit against the insured seeking damages on account of property damage, even if the allegations are "groundless, false, or fraudulent." It is uniformly recognized that the insurer's defense obligation is broader than its duty to indemnity. Generally, the insurance company must defend any suit against the insured which, if proven, would bring the case within coverage. The term "suit" has been held to include even adjudicatory proceedings before administrative agencies, such as the Environmental Protection Agency.

This duty to defend may arise even before suit is actually filed. Some courts have found that formal initiation of a lawsuit is not necessary to trigger an insurer's duty to defend. Those courts held that a letter from an environmental regulatory agency, such as a letter sent to all potentially responsible parties, is the first step in a coercive legal process which requires the same response from a recipient as that required should an agency choose to sue. The agency's statutory authority to enforce cleanup liabilities on private parties without resorting to the courts has been a significant factor in court decisions that consider agency enforcement letters as "suits," thus triggering the duty to defend.

In conclusion, coverage for cleanup costs and damages caused to property by pollution may be available under some or all CGL policies. Moreover, legal fees incurred in defending lawsuits in dealing with governmental regulators also may be covered under CGL policies. Therefore, a thorough review of applicable comprehensive general liability policies should be made when considering a situation involving environmental contamination.

Write in 327 for more information.

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Typical bioremediation project of petroleum contaminated soil

Write in 036 on inquiry card.

January-February 1991 Soils 23
Refining the market

Company recycles used oil into on-spec fuel products

By Darcy V. Case

Only about half of the 800-plus million gallons of waste oil generated each year in the U.S. is recycled, according to recent national estimates. Much of the remainder eventually makes its way into the soil. When it does, it can pose more of a hazardous risk than virgin materials because of the wear metals it contains.

International Recovery Corp., (IRC), Miami Springs, Fla., is one company that is making a dent in this increasing problem by recycling used oil and re-refining it into marketable fuel products.

The company collects waste oil from more than 11,000 gas stations, quick lube shops and other industrial operations across the Southeast, and recycles it into fuel used in phosphate mining and other industries.

In IRC labs, the oil is analyzed to determine water content, gravity, viscosity and flash point among other things. The oil is re-refined to meet Environmental Protection Agency (EPA) classifications equivalent to virgin products, says Howard Goldman, IRC’s marketing director.

Recycled fuel products have a lower sulfur content and a more consistent viscosity than virgin material, says Don Van Sickle, manager for IRC’s International Petroleum Corp, a Florida-based subsidiary.

“Viscosity is the key to proper atomization for burning,” Van Sickle says. “Fewer adjustments are needed in customers’ burners (with consistent viscosity). It’s a more ‘steady’ operation.”

The oil is reclaimed through atmospheric and vacuum distillation.

In the atmospheric distillation process, the oil is heated to the boiling point to produce steam. “At this point, the light end products are vaporized,” Van Sickle says. These products are then cooled and condensed back to a liquid and stored for use in fueling the treatment facility itself. The emissions of the treatment plant become carbon dioxide and water.

“Throughout the whole process, no waste material is generated,” Goldman says. The remaining oil is continually filtered and processed in a closed system under vacuum distillation until it is ready to ship.

Cost of the reclaimed oil is usually five to 15 percent below that of virgin materials, Goldman says. The company produces a range of grades of fuel including industrial diesel, No. 4, No. 5, and No. 6. “We re-refine the used oil into an on-spec fuel product, according to the customer’s need,” Goldman says.

The treatment facility

The treatment facility is a two-in-one operation. The water from the waste oil is distilled in a wastewater treatment section of the plant, and then discharged by permit into the local water treatment system for municipal recycling. The waste oil

International Recovery Corp.’s oil re-refining plant in Miami Springs, Fla., where over 20 million gallons of used oil is recycled each year.

The market

About 50 percent of the company’s recycled oil is sold to the phosphate industry, which uses it to separate the phosphate ore from the tailings. The re-refined products also are used by citrus, marine, nursery, utility, sugar, chemical and other industrial burning facilities such as asphalt plants and those that operate cement kilns.

IRC’s recycling facility in Plant City, Fla., has a 30-35 million gallon capacity for oil conversion, Goldman says. In 1988, it recycled 18-19 million gallons, and in 1989, it ran 22-24 million gallons.

IRC, which has been in the oil
refining business through predecessor companies for over 40 years, purchases the used oil from independent collectors, who generally pick up oil at no charge from generators of the waste. The cost of the used oil depends on supply, demand, quality and quantity of oil and other factors, Goldman says.

IRC also purchases slop oils from principal refineries, and contaminated and used oil from within the industry. IRC usually pays for used oil; however, depending on contamination of the stock, it will also charge for it. For example, it may levy a fee to handle contaminated materials from the industry and other large-quantity generators. IRC also charges when the used oil's water content is high.

Classification as hazardous waste?
Since 1984, legislators have debated over waste oil classification—hazardous or non-hazardous. IRC's oil recycling operations have historically been profitable at a time when used oil is considered non-hazardous.

Goldman says if waste oil is reclassified as hazardous, IRC's profits would increase, but it would also lead to more illegal dumping.

"We would be even more profitable as we would be able to charge more for the collection of the waste oil, but we feel that it would add to an already sensitive environmental problem," Goldman says. "Are people going to dump more or pay more?"

In addition to oil re-refining, IRC provides comprehensive environmental services through its other subsidiaries which include thermal soil decontamination, wastewater treatment, laboratory analysis, site assessments, remediation services, underground storage tank installation and decommission. Separately, IRC markets aviation fuel to large non-major commercial aircraft and corporate customers. More than half the company's profits are derived from fueling airplanes at nearly 1,000 airports in more than 140 countries.

Write in 328 for more information.
Over half of the oil-refining of California lies within 20 miles of the Port of Los Angeles, making it a major hub for the handling of crude oil and petroleum products. Like many ports, it has been involved in the import and export of petroleum products since the early 1900s. And, like many ports, it is now facing soil and groundwater contamination problems.

Petroleum and petrochemical products are handled at the Port's terminal facilities which are leased to oil companies. In 1911, the Port handled one million barrels of oil. That number reached 175 million barrels during 1987-88. Facilities range in size from small marine fuelling stations to major petroleum terminals. The Port has 19 berths handling crude oil or petroleum products for 15 separate terminal operators. There are 20 separate active tank farms and three decommissioned former tank farm sites. Among the facilities at Worldport LA, there are approximately 500 above-ground storage tanks with 500 million gallons of storage capacity.

The Port now plans an approximately $1 billion, five-year capital development program, but must first handle its petroleum hydrocarbon contaminated soils.

**Marine terminal hydrogeology**

The 7,000 acre land and water
Table 1. Seven large and medium size West Coast ports were surveyed during August 1990 to determine their involvement with the characterization and remediation of these soils.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>U.S. Port Survey—Hydrocarbon Contaminated Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Ports surveyed</td>
<td>7</td>
</tr>
<tr>
<td>Ports indicating hydrocarbon contaminated soils a problem</td>
<td>7</td>
</tr>
<tr>
<td>Problems associated with present or former above ground storage tanks</td>
<td>7</td>
</tr>
<tr>
<td>Site characterization and remediation work in progress</td>
<td>7</td>
</tr>
<tr>
<td>Regional soil remediation sites planned or established</td>
<td>4</td>
</tr>
<tr>
<td>Contamination encountered during construction</td>
<td>6</td>
</tr>
</tbody>
</table>

area of the Port has shallow ground water conditions coupled with tidal influences. This shallow ground water depth enables monitoring wells to be drilled and constructed with small track-mounted drilling rigs or, in some cases, even by hand methods. In the case of Worldport LA, this is invaluable since the high retaining walls of the bulk terminals allow limited working space.

Past studies of the Port area have shown that the shallow aquifer generally consists of approximately 10 feet of dredged harbor fill which sits on natural sediments of marine clay and silt. The natural sediments have been found in one study to be of much lower permeability than the overlying fill.

Tidal influence has been found to be limited because of the relatively low permeability of the fill which comprises the uppermost shallow aquifer. So, contamination derived from surface spills or releases is retained, or its vertical movement retarded, by this low permeability layer.

Cleanup program
Two remediation projects of petroleum hydrocarbon contaminated soil are now underway at the Port. Site 1 involves an area where a grain terminal, built in the 1920s, was being removed to allow the expansion of a cargo terminal. The site is bordered on the west and south by petroleum tank farms and on the east by harbor waters.

During the last phase of the demolition of the grain terminal, evidence of soil contamination from petroleum hydrocarbons was leaked. These four pipelines were removed by their owners, three oil companies and the Harbor Department, and the presence of petroleum hydrocarbon contamination (see Table 2) in the soil was confirmed. The petroleum could not be definitively identified, but appeared to be of a heavy petroleum type (diesel, bunker oil or possibly very weathered crude).

Continues on page 42

Table 2. Maximum soil contamination levels found in the initial site characterization at Pipeline Site 1, Port of LA.

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total petroleum hydrocarbon (EPA Method 4181.1)</td>
<td>69,300</td>
</tr>
<tr>
<td>Total petroleum hydrocarbon (EPA Method 8015 modified for diesel)</td>
<td>43,000</td>
</tr>
<tr>
<td>Benzene</td>
<td>40.7</td>
</tr>
<tr>
<td>Toluene</td>
<td>102</td>
</tr>
<tr>
<td>Xylene</td>
<td>67</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>171</td>
</tr>
</tbody>
</table>

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Write in 037 on inquiry card. January-February 1991 Soils 27
Buying and selling contaminated land

Understanding liability, responsibility makes transactions easier

By Gregor I. McGregor

It is possible to buy and sell dirty property. This little-known fact is lost amid the noise and fury over Superfund liability for contaminated land.

Often, however, the discovery of contamination on real estate is the kiss of death for a land transaction. The label “hazardous waste” spooks buyers, brokers, and banks and causes sellers and brokers to lose sleep.

This is natural, considering that landowners can be liable for buying contaminated land even if they were not aware of the contamination at the time of purchase; even if the actions which contaminated the land were legal at the time; and even if the contaminated land is sold “as is” with full indemnification contract clauses.

Contamination can also trigger strict liability under federal and state Superfund laws. This special liability can reach even innocent landowners and lenders, imposing cleanup obligations.

But, almost all hazardous waste problems are manageable.

The slightest mention of contamination should not create unreasonable fear, and the presence of contamination doesn’t render property unsalable. Knowledge of the extent of contamination and of cleanup methods available, along with carefully crafted real estate documents to allocate financial responsibilities and cleanup duties, can help make a dirty mess into a successful, profitable real estate transaction.

Cleanup costs can be paid from Superfund or reimbursed by responsible parties. There are some limited defenses against Superfund liability for innocent landowners and for contamination by third parties. Parties, known as Potentially Responsible Parties (PRPs) in Environmental Protection Agency (EPA) lingo, who pay to clean up contamination can go after the Real Responsible Parties for contribution.

Understanding hazardous material liability

Liability under Superfund and similar state statutes is considered strict, joint and several, and retroactive. Accordingly, all generators and transporters of hazardous waste, past and present, and all owners and operators of facilities, from which there has been a release or threat of release, are liable for the resulting cleanup costs, without regard to fault. Thus, EPA does not need to prove wrongdoing, such as negligence, in order to compel cleanup or recover response costs.

And, where the contamination is not divisible, each PRP may be held liable for the entire amount of cleanup or other response. Thus, EPA may seek recovery from any or all responsible parties. The unlucky “deep pocket” may be obligated for the full amount. EPA doesn’t need to establish who was responsible for exactly how much waste, and may select from among the site owners or operators (past or present), generators or transporters.

Liability is “retroactive” as it attaches not only to present but also to prior owners and operators of the site at times when the releases took place. This feature, coupled with strict liability, changes drastically the old practice of selling property “as is.”

Any party may be liable for punitive damages up to treble the costs incurred by EPA for failing to properly provide response action in accord with a formal EPA administrative order. Such treble damages may be imposed on top of the actual cleanup costs.

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Gregor I. McGregor is founding partner of McGregor, Shea & Doliner, an environmental law firm in Boston, Mass.
Remember that Superfund liability attaches to any real estate contaminated with Superfund hazardous materials, regardless whether or not the site is listed on the National Priority List (NPL). This is why Superfund liability reaches almost anyone having anything to do with real estate.

Several states have also created their own superfunds. These state statutes, which Congress has invited to go beyond the federal Superfund, commonly regulate more types of waste (such as petroleum products), impose stricter liability (allowing fewer defenses), foster additional litigation (allowing private suits for damage to real estate) or affect real estate title (allowing the state to record a superior lien, known as a Superlien, to secure reimbursement of cleanup costs).

Contamination...routine?

Almost every piece of industrial or commercial real estate, and most agricultural properties, will have some contamination, especially as we approach the 21st century. Expect it. Commercial buildings, clean-looking factories, and unimproved land can also be victims of contamination.

EPA under Superfund has catalogued about 1,200 sites—only the tip of the iceberg. Tens of thousands more sites will be discovered. Eventually, dealing with contamination will be routine.

Assessments control risks

Because the presence of hazardous waste may not be readily apparent, it is critical to evaluate property thoroughly before closing a real estate transaction. But realize, you will get what you pay for in a site assessment. Choose contractors wisely.

Avoid contractors who own-ball their proposals only to do quick studies recommending further studies. Avoid those who send you contracts dripping indemnification clauses and limits on financial liability for negligence. Avoid those who send teams of junior people right out of school with no supervision by senior engineers or environmental scientists.

A properly done site assessment should include a physical survey, specifically: topography, geologic setting, surface and groundwater flows, building and utility layouts, and the condition of all above and below ground buildings, along with tanks and piping. The assessment should also include permit and enforcement history of the property. Of course, the proper site assessment is not limited to hazardous waste but includes other hazardous materials, as well as air and water pollution.

Structuring the transaction

Contract clauses that minimize financial exposure are

Continues on page 30→

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backstops. Control of the cleanup and the timing of ownership is a more powerful tool. One way to structure this is to delay the closing (and thus, ownership of the waste) until cleanup is complete. Another way is to hold back purchase money or put it in escrow until the property is clean enough (according to the buyer’s experts).

Yet another way is for the buyer to conduct a cleanup (so it is done right) and to deduct cleanup costs from the purchase price. Or, the buyer may want to close on the property with the seller granted access to do a cleanup at no cost to the buyer. Or, create a contract sharing cleanup duties between buyer and seller, with explicit division of labor (preliminary investigations, notices to agencies, remedial action plans, supervising contractors and doing the cleanup).

Use contract clauses carefully
Utilizing contracts to allocate costs and risks can provide needed comfort when purchasing land, contaminated or not. Be aware, however, that contract clauses themselves do not necessarily relieve buyers and sellers of legal liabilities when property is contaminated with hazardous waste.

Contracts can share or shift the financial burdens, but Superfund itself provides that the fundamental legal liability remains.

Indemnification is the basic agreement: one party, usually the seller, agrees to reimburse the buyer for all or part of the expenses arising out of cleanup.

Fine points in the contract may include: escrow deposits, purchase money holdbacks, a reimbursement formula, progress reports, cooperation in insurance claims, “hold harmless” arrangements against third party claims and government cleanup orders, and contingencies about future claims in case more cleanup is needed.

Other distancing techniques
Since ownership or operation of a contaminated site triggers liability, carve off the contamination. Buy equipment or other personal property rather than the real estate. Lease the clean part of the premises, not the dirty part. Lease only the surface of the floor and the space above. Create a new corporate subsidiary for the clean part of the operation, and buy it. Buy only an easement or air rights.

Within a project, having no direct participation with waste generation or disposal has isolated the buyer from liability. In court, the key appears to be who makes or has the authority to make the hazardous waste operation, production, or disposal decisions, or oversees that area within the business. Sophisticated buyers now explore participation as a limited partner, through a subsidiary, or by owning a limited economic interest in a project, excluding interest in the real estate. The point is to avoid the degree of managerial involvement (e.g., overseeing day-to-day activities) that constitutes “owner-

ship” or “operation” of a facility under Superfund.

Lender considerations
Often banks and other lenders are reluctant, with reason, to finance buyers of contaminated property. Court cases have held them liable under Superfund if they own the property, even briefly, if they get too involved in borrower operations, or if they have the authority to control the operations—even if they don’t exercise it. Bills are pending in Congress to deal with this nightmare of lender liability.

In addition to lender liability issues, property taken as collateral may lose value once hazardous waste is detected. Or, the borrower may not be able to repay the mortgage if also forced to bear the costs of cleanup. Or, the lender may lose priority to a cleanup lien filed by a state agency in one of the states with a Superlender provision in the state Superfund law.

The “careful” bank requires a proper site assessment, along with written representation about the absence or condition of any known contamination either on the property or on the neighboring property that could migrate. The bank also requires the buyer to give prompt notification of any contamination discovered during the term of mortgage.

The bank also might insist on indemnity from borrowers and guarantors or may condition the loan on cleanup. It may also adjust interest rates to reflect risks or take personal guarantees to back up usual security.

Dealing with contamination—daily
Everyday, many more contaminated sites will be discovered—as buyers, banks and investors get more sophisticated, as chemical testing improves and as government reporting obligations increase—and these sites will turn out to be the land and buildings involved in typical commercial transactions.

Realizing that contamination is routine has made proper hazardous waste management a fundamental legal requirement governing federal, state, local government and business operations. Strict liability for releasing hazardous substances into the environment is here to stay, and the courts are willing to enforce these new forms of legal obligations. EPA and state agencies are gaining new enforcement tools such as administrative penalties and new cleanup authorities to deal with contaminated sites.

Knowledgeable landowners should be aware of the Superfund defenses that may be invoked and operate in a manner that allows them to use those defenses. They also need to be aware of claims they can pursue using Superfund provisions, indemnification clauses in real estate contracts and theories of contribution. Landowners should keep track of costs so as to seek reimbursement. It makes sense for businesses to cope with Superfund responsibilities using practical approaches to minimize the legal, financial and environmental risks.

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▷ Back-fit equipment for your existing Rotary Dryers/Kilns
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---

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COMPANY _______________________________________
ADDRESS _______________________________________
CITY ___________________ STATE _____________
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Write in 038 on inquiry card.
The *in situ* vitrification process

**In situ vitrification,** from page 7

those that are not destroyed are extracted out of the ground at the collecting hood where they burn in the presence of oxygen. The fumes captured by the hood are drawn to the off-gas treatment trailer where they undergo a quenching, scrubbing, filtration, and carbon absorption process that produces an environmentally safe emission.

Hansen points out that if there is too much organic material in the soil, the capacity of the induction fan may be exceeded, but he says this situation can be dealt with in advance by mixing uncontaminated soil into the contaminated zone, thereby reducing the percentage of organics.

**A look at the costs**

Large-scale studies conducted by PNL show that the time needed to complete the melt at one setting of the electrodes depends on the size of the area being remediated, but the SVE system can steadily process five tons of soil per hour. Depending on the cost of electricity at the site, the price to the customer for vitrification services will range from $275 to $375 per ton, not including the costs of treatability testing, mobilization, and demobilization. Geosafe estimates that an average site will involve the processing of 10,000 to 15,000 tons of contaminated soil. According to a recent press release from Geosafe, the cost of treating approximately 2,600 tons of PCB-contaminated soil at a Superfund site near Spokane, Wash., will exceed $1 million. Remediation work on that site is scheduled to get underway this month.

Hansen said ISV is not competitive with "low-cost systems on easy sites," but it is competitive with other technologies now being used on sites that are considered difficult to remedy.

"In the more difficult sites, ISV is often identified as the most cost-effective technology," he says. The reason for that, he explains, is the ability of ISV to simultaneously take care of organic and inorganic waste in a one-step process.

Hansen also pointed out that there isn't any need to haul away the glass-like monoliths that lie buried underground when the ISV process is completed.

"Why move something away that's no longer a problem?" he says. Write in 331 for more information.
Air movement, from page 20

with horizontal vents in which the vacuum pipes are buried in trenches. This treatment strategy is used when the water table is only a few feet from the surface. In a test project completed last summer at a sandy site contaminated with gasoline in northwest Indiana, Griffin used plastic sheeting applied to the surface of the ground to help improve the sealing of the horizontal vents. Green says an even better seal can be achieved by removing sod and applying bentonite, a natural clay that swells when it's wet. Bentonite is also used in vertical vents to help seal the bore holes.

The use of plastic sheeting or other means to seal the surface is one example of a field application that is still awaiting a verdict from scientists. A team of researchers, including two from Utah State University and two from the EPA Environmental Research Laboratory at Ada, Okla., suggested that "the effect of engineering modifications such as surface sealing should be demonstrated during a field test to assist others in determining whether to use similar modifications at other sites."

The same research team questioned the value of using SVE to remediate clayey soils which are highly impermeable. In a report completed last summer, the team noted that air flow in these soils may not be uniform, resulting in "relatively rapid removal of VOCs (volatile organic compounds) present in preferential flow areas with much slower removal in areas of lower permeability."

The basic message in this report and others that have been completed during the past few years is that controlled field tests—more of them—will help answer many of the questions that intrigue researchers and commercial developers who see SVE as an effective remediation technology. Its use as a stand-alone method is gaining widespread acceptance, and it has also been used to enhance the biogradation of petroleum hydrocarbon contamination by increasing soil oxygen levels.

There seems to be no doubt that SVE has become one of the important tools in the soil remediation toolbox. And, as greater scientific and technological understanding of it increases, commercial applications will be developed to meet almost any need. That's not a bad record for a technology that is barely eight years old.

Write in 326 for more information.

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Write in 010 on inquiry card.

January-February 1991 Soils 33
Astec’s six-load portable thermal treatment plant
Asphalt facility designer plans to produce remediation plant

Astec Industries, Chattanooga, Tenn., a company specializing in asphalt plant design, announces plans to produce portable soil remediation plants.

The six-load thermal treatment plant can be moved in six loads and is capable of processing from 30 to 50 tons of contaminated soil per hour. It features a durable cold feed unit, a high efficiency burner, drum and dual cyclones, an upright afterburner, a cooling chamber, as well as a baghouse and control house.

Astec has also developed a unit that can be fitted to an existing asphalt plant.

Write in 332 on inquiry card.

EBW offers vacuum vent for underground tanks

EBW, Inc. of Muskegon, Mich., introduces an improved vacuum vent for dispersion of upward vapor discharge from underground tanks.

The 802 Tank Vent is listed with Underwriters Laboratory and features cast aluminum construction, 30 mesh (flame arresting) bronze screen, and “O”-ring with locking screw for unthreaded installation. An 8 ounce, pressure relief poppet and a 1/2 ounce vacuum poppet maintain the balance of vapor pressure within the underground tank.

Write in 333 on inquiry card.

Hazco catalog features sampling equipment

Hazco Services, Inc., Dayton, Ohio, releases a 32-page catalog featuring environmental sampling equipment and supplies for soil, water, air and waste.

Products include air monitoring instrumentation, water quality equipment, bailers, gas vapor probes, soil augers and samplers, sample collection and transportation devices, along with personal protective equipment and clothing.

The equipment is stocked in four distribution facilities nationwide and can be rented on a daily, weekly or monthly basis. For a complimentary copy: 2006 Springboro West Road, Dayton, Ohio 45439 or call 800-332-0435.

Write in 334 on inquiry card.

Photo-ionization device detects hydrocarbon gases, vapors

A hand-held gas detector that measures low concentrations of hydrocarbon gases and vapors is now available from MSA, Pittsburgh, Pa.

The Photon™ Gas Detector can be used at HazMat sites for assessment of toxic gases and vapors and leak detection of volatile organic compounds (VOCs). The detector measures concentrations of hydrocarbon gases and vapors ranging from: 0.1 to 2,000 ppm. Results are displayed on the unit’s two-line, liquid crystal display.

Write in 335 on inquiry card.
Remedial Systems introduces portable gas recovery units

Remedial Systems, Foxboro, Mass., introduces new soil gas recovery units, which are skid mounted for portable use, requiring only a pickup truck for transport.

These explosion proof units provide quiet operation with a little air temperature rise, according to the manufacturer. The controls can be monitored and operated from a remote office using telemetry.

Write in 336 on inquiry card.

Correction

Due to lack of space in the November-December 1990 issue, these charts were not published with the article titled, "On-Site Answer to ‘Cradle to Grave’ Liability" by Jeffrey Powell and Elaine Macinski on pages 24-25. We regret the omission.

Typical Pre-Burn Soil Analysis

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Typical Post-Burn Soil Analysis

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Air Emission Stack Test Results

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Rosemount Analytical releases new analyzer, brochure

The Dohrmann Division of Rosemount Analytical releases the DX-25 Volatile Organic Halide Analyzer and offers a four-page, two-color brochure highlighting their laboratory analyzers, including total organic carbon analyzers, organic halogen analyzers and trace element analyzers for sulfur, nitrogen and chlorine in hydrocarbons.

The DX-25 screens samples of drinking water, groundwater and soils for contaminants.

The analyzer can be used to determine the extent of volatile organic halide contamination and can screen water samples prior to gas chromatography to determine the actual concentration range of volatile organic halides.

Write in 337 on inquiry card.

CEA's dual analyzer

Portable analyzer measures concentration of two gases

CEA Instruments, Inc., Emerson, N.J., introduces the LFG 10, a portable carbon dioxide and methane dual gas analyzer that uses non dispersive infrared absorption to monitor gas concentrations in the air.

An internal pump in the LFG 10 draws the air being analyzed into the instrument via a stainless-steel handheld probe.

Separate three-digit liquid-crystal displays indicate the concentrations of both gases and switch automatically between 0-10 to 0-100 percent ranges, as appropriate.

Write in 344 on inquiry card.
Industry news

Ogden merges with company to utilize kiln technology

Ogden Environmental Services, Inc. (OES), Fairfield, NJ, is planning to merge with American Envirotech, Inc. (AEI), a Houston, Texas, based company that is developing a project to destroy hazardous waste by incineration.

A facility, which will utilize rotary kiln technology, will cost $60 million to construct and could be operational by 1993, according to Brian Delle Donne, president of OES.

Write in 338 on inquiry card.

Beazer provides environmental construction services to clients

Beazer Environmental Services, Inc., Pittsburgh, Pa., is providing environmental construction services to U.S. and worldwide clients.

Beazer, an international construction and house building group, now provides contracting for groundwater extraction and treatment facilities; wastewater treatment plants; operation and maintenance of water/waste treatment plants; soil and water bio-treatment applications; and engineering services.

Write in 339 on inquiry card.
People and places

Vapex names president, technical director

Vapex Environmental Technologies, Canton, Mass., names Donald Jacobs as president and chief executive officer, and Michael C. Marley as director of Technical Development. Jacobs brings 20 years of senior management experience to Vapex. Marley has more than 12 years of experience in environmental engineering and is nationally recognized for his work in the modeling, design and implementation of soil vapor extraction systems.

Write in 340 on inquiry card.

Bioremediation cleans up site

Ecova Corp. recently cleaned up 17,000 cubic yards of pentachlorophenol (PCP) and creosote-contaminated soil at the 30-acre Brooklyn Center, Minn., Superfund site.

A bioremediation program reduced concentrations of PCP from levels measured at 360 ppm to 10 ppm.

Write in 341 on inquiry card.

Liquid samplers aid military in desert

Southern Eastern Liquid Analyzers, Inc., York, S.C., is donating specially calibrated liquid samplers to U.S. military forces in Saudi Arabia to use in their field refueling operations.

These samplers will be used to inventory and check for water and other contaminants in mobile fueling tanks.

Write in 342 on inquiry card.

Calendar of Events


WANTED: REMEDIATION TECHNOLOGIES FOR FIELD DEMONSTRATIONS

A utility company is planning to conduct field demonstrations of treatment technologies capable of remediating a manufactured gas plant (MGP) site. Only technologies proven at the bench-and pilot-scale and ready for field demonstration will be considered. Interested parties should submit a letter of interest that: (1) provides a technology description, (2) demonstrates the scale of technology development, and (3) describes treatment capabilities for MGP site wastes. The letter-of-interest should be submitted no later than Feb. 28, 1991.

Technology Demonstration
P.O. Box 38427
Pittsburgh, PA 15238

Write 042 on inquiry card.

January-February 1991 Soils 37
When identifying petroleum products that have been released into the environment, the most asked questions are: What petroleum product is present? Whose product is it?

Investigating a hazardous waste spill involves taking a close look at the detailed signature of a petroleum product. It is well documented that crude oil is made up of tens of thousands of individual compounds. These vary slightly from batch to batch depending on refining, weathering and handling processes to create unique chemical signatures. Gasolines from different storage tanks can often be differentiated even if they are filled from the same gasoline tank truck. The specific test used for discrimination depends on the petroleum product, the past treatment of the material and the specific questions required by the investigation.

**GC Identifications**

Gas chromatography (GC) is an analytical tool used widely in hazardous waste investigations. It is well suited for the analysis of volatile and semi-volatile organic compounds.

Volatile and semi-volatile petroleum products usually have “characteristic” GC traces. Because the suppliers of petroleum products generally use the same type of starting material, such as crude oil, the end products are often similar in their GC signatures. The use of other starting materials, such as coal, will generate products that look similar to each other but differ from products derived from crude oil. Each product generally has some unique characteristic which allows an investigator to distinguish it from others.

In addition to the various types of automobile gasolines such as leaded, unleaded, regular and premium, there are also a number of aviation gasolines in wide use. GC analysis can be used to quickly identify gasoline contamination from other products such as diesel fuel and motor oil. However, to distinguish between the various types of gasolines other tests are sometimes needed. The more the analyst knows about the materials that may be involved, the better he can select the appropriate tests. Sometimes the presence of a single additive eliminates all but one possibility.

**Gasolines** are currently very sophisticated fuels and are often blends of refinery products. Examples of the GC signature of two gasolines are shown in Figures 1 and 2. Gasolines contain hydrocarbon compounds the majority of which elute from ca n-C4 to n-C10 with a maximum near n-C5. There are compounds that fall outside this range, however their contribution to the total mass of material is small. The gasolines have high levels of benzene, toluene, ethylbenzene and the xylenes. These compounds have high octane ratings. The remaining compounds are generally straight chain and branched chain alkanes most of which have low octane ratings. Because of the restriction on the lead content of gasolines, the formulations have changed in the last few years and petroleum blends (reformate) having high octane ratings are blended in to meet specified octane requirements.

**Turbine fuels** are oils that are very clean burning fuels and are used to power turbine engines. These oils are generally straight run petroleum distillates (little blending occurs) which have low residues after burning. (Examples of some are show in Figures 4 through 6 on page 41.) As in the starting crude oil, there is a predominance of the n-alkanes, with the branched alkanes, alkenes, aromatic hydrocarbons and other compounds appearing as small peaks between the dominant n-alkane peaks. There are four standard turbine fuels in wide use in the United States. These are JP-4, JP-5, Jet A and kerosene. Others are available but are often just special refinements of one of these major types.

**Turbine fuels** beginning with JP are turbine fuels that have been developed for military use. JP-4 is the turbine fuel used by the U.S. Air Force. It is a highly volatile fuel containing hydrocarbons that elute on the GC from ca n-C4 to n-C16 with a maximum near n-C6. It can be distinguished from gasoline by the predominance of the n-alkanes, low levels of benzene, toluene, ethylbenzene and the xylenes, as well as the amount of material eluting past ca n-C10. JP-5 is the turbine fuel used by the U.S. Navy. To reduce the chance of fires on board ships, the highly volatile hydrocarbons found in JP-4 are absent in JP-5. JP-5 contains hydrocarbons that elute on the GC from ca n-C10 to n-C19 with a maximum near n-C13.

**Commercial jet fuel (Jet A)** is very similar to JP-5 and sometimes is indistinguishable by GC analysis. Often Jet A will have more small

---

Andrew J. Friedman and James E. Bruya are founders of Friedman & Bruya, Inc. Environmental Chemists, in Seattle, Wash.
peaks present before the main hump of hydrocarbons that elute from ca n-C10 to n-C19 with a maximum near n-C13. Jet A and JP-5 can be distinguished by the presence or absence of specific fuel additives.

**Turbine fuel used in land based turbines** is sometimes called kerosine. These are very clean burning fuels and are similar to Jet A and JP-5 in the types of hydrocarbons that they contain. The flash point and distillation end point of the various kerosines determine their actual elution range on the GC but these generally fall within the range of from ca n-C10 to n-C18.

**Diesel fuels** are oils that are used to power diesel engines. These oils differ mainly from turbine fuels in the amount of residue left after burning. There are a number of diesel fuels that are widely used. The climate often dictates the type of diesel fuel used in a particular area. Arctic diesel, diesel #1 and marine diesel are light diesel fuels that elute on the GC from ca n-C8 to n-C19. These materials are often used in very cold climates. They have a relatively low flash point, thus they contain some of the highly volatile compounds. Diesel #2 (see example, Figure 3) is a heavier diesel and the hydrocarbons that are present in this material elute on the GC from ca n-C9 to n-C21. Even heavier diesels are available such as diesel #4 and #6. These latter fuels are blends of a diesel distillation fractions with residual oils. They often are inexpensive, have low BTU ratings (less alkanes and more aromatic hydrocarbons) and some show very unique GC signatures.

**Thinner and solvents** are specialty products with very specific chemical characteristics. The GC signatures are characterized by a series of peaks that elute in a very narrow range with few peaks found before or after. Often they are highly refined materials and do not show the predominance of the n-alkanes that dominate the GC signatures of the straight-run petroleum distillates (turbine fuels and most diesels). Most of the thiner and solvents elute before ca n-C14.

**Lubricating oils (motor oil)**, hydraulic fluids and other heavy petroleum products such as Bunker C, tars, creosote and asphalt are not easily analyzed by GC. The individual compounds that make up these products are sometimes considered to be non-volatile and are not applicable to GC analysis. One must be very careful in interpreting these GC signatures. For example, the signature shown for motor oil displays an apparent peak near 30 minutes. This peak is actually an artifact caused by the conditions used to inject this sample into the GC. Most of the compounds that make up motor oil are so heavy or non-volatile that they do not vaporize and travel through the GC column, but rather are left behind in the GC injector. This results in the artificial drop off seen near 30 minutes. Special GC conditions and GC columns can be used to better characterize these materials. Currently, a special GC column is used to analyze up to ca n-C45. However, liquid chromatographic systems are often more suited for the analysis of these materials.

**Weathering petroleum products**

Once a petroleum product is manufactured, it begins to weather. Highly volatile compounds will vaporize and be lost whenever an air space develops. Water soluble products will be removed upon contact with water. Chemical oxidations will occur in oxidizing environments and biological degradations will occur along surfaces in contact with water. Each of these weathering processes will change petroleum products in predictable ways. The speed of weathering is slow when the petroleum is confined to a tank and can be very fast when released into the environment.

Gasolines released into the environment will mainly weather by volatilization and/or solubiliza-
Fingerprinting Crude, from page 39

...tion processes. The volatile components are quickly lost once the fuel is released from an enclosure such as a sealed tank or other container. Factors that will effect the speed of volatilization include the actual thickness of the spilled petroleum, the volume of air above the gasoline and the movement of that air away from the spill. The GC signature will appear to lose the most volatile hydrocarbons first. What happens is that the more volatile compounds are being lost faster than the less volatile compounds. This means that the peaks near n-C5 will appear to decrease in size relative to the peaks near n-C10.

Solubilization is a weathering process where water removes the water soluble compounds. Factors that affect the rate of solubilization include the amount of water and speed of water movement through the gasoline, as well as the movement of water under the gasoline/water interface. The thickness of the gasoline spill will also greatly affect the rate of solubilization. Compounds that are removed from the gasoline by water include benzene, toluene, ethylbenzene and xylenes. Some of the new gasoline additives such as t-butylmethyl ether may also be removed.

Fluctuating water tables will greatly increase the rate of the weathering processes since they will increase the effective interface area of the gasoline, water and/or air. Vaporization within a soil column will also increase because of the increased air movement above the gasoline caused by the fluctuating water table.

Turbine fuels and diesel fuels weather mainly by volatilization and oxidation. Volatilization will occur as with the highly volatile gases but at a slower rate. The more volatile components will appear to be lost first and the suite of peaks will appear to shift to longer retention times. JP-4, more volatile than JP-5, Jet A, or diesel #2, will weather fastest by volatilization.

Oxidation processes will reduce the n-alkanes’ dominance in the GC signatures of turbine and diesel fuels. The relative height of the n-alkane peaks will decrease relative to the peaks found between the n-alkane peaks. Biological oxidations have the interesting effect of selectively removing one or more of the n-alkanes. Many of the biological systems will tend to remove the even n-alkanes (C16, C14, C12, etc.) in preference to the odd n-alkane. The result is a saw-toothed n-alkane pattern.

Fingerprint identifications

Occasionally, it is important to try to match a petroleum product found in the ground to material that may be or may have been in one of several tanks near by. This can be a very complex situation for a chemist because each batch of petroleum has its own unique chemical signature and weathering of the petroleum in the ground will further change its signature from that shown by the material still in the tank.

When a spill is fresh (has not undergone extensive weathering), and the suspect tank has not been refilled, a good match or non-match can often be obtained. In cases where weathering of the spilled material has occurred, comparison of the relative peak heights of specific individual peaks can be used to confirm matches. The peaks used for comparing different batches of petroleum product depend upon the GC conditions used by an analyst. It is preferable to use peaks that represent individual hydrocarbons which are comparable to each other in volatility and water solubility. Laboratories wanting to do this type of work must first establish extensive data bases showing standard variabilities among the peaks selected for matching purposes. Once this is done, the analyst can then begin to fingerprint samples to determine if the
Gas chromatographic signature charts separate a matrix into its individual components. As chemists improve the identification capabilities and sensitivity of their analytical instruments, more compounds are identified. When before only one broad peak was seen, ten or more new peaks are now found.

Variations seen are sufficient to say that one has the same or different batches of a petroleum product. If the spill occurred sometime in the past or is the result of a slow release from a tank that may have been filled many times during the release period, fingerprinting the spill is much more difficult. In these cases the sampling plan is very important. Samples must be taken and then analyzed to show a step by step trail of the contamination back to the source. The steps must be small enough to have comparable chemical signatures between sampling locations. Sampling must also be done to show that negative results or non-matches are found when moving away from the actual contamination path.

**Leave more detailed identifications to experienced analysts**

It is relatively easy to distinguish between low boiling, moderate boiling and high boiling products such as gasoline, diesel and motor oil. More detailed or precise identifications of petroleum products is often dependent upon the experience of the analyst.

Detailed identifications are complicated by the variability between each batch of petroleum product, as well as weathering effects and other degradative processes. It is sometimes possible to distinguish between batches of petroleum products by looking for additives that are in one batch but not the other. At other times the relative heights of the various peaks present in the GC signature can be used to show similarities or dissimilarities between specific batches of petroleum products.

Write in 343 for more information.
Port on the move, from page 27

rather than gasoline. The volume of contaminated soil was estimated to be 1,500 cubic yards of the most heavily contaminated soil from the site. The cost of this activity was shared equally by all four pipeline owners. However, there remained 2,000 cubic yards of soil with unknown levels of contamination stockpiled at the site due to additional contaminated soil discovered during excavation. The Harbor Department decided to bioremediate the remaining soil and an environmental consultant was contracted.

The consultant first sampled the stockpiled soil and determined that with disposal of the heavily contaminated soil, most of the petroleum hydrocarbon and all of the aromatic hydrocarbons, were removed (see Table 3 on right). Also, analysis indicated the soil qualified for classification as a California designated waste rather than a hazardous waste. Designated waste is a less restrictive category under California environmental regulations when compared to hazardous waste and has the advantage of requiring fewer permits if treatment of the waste is planned.

The bioremediation phase of the project is designed around a supplied air bioremediation pile within an area of about 300 feet by 75 feet. The soil is placed on a perforated system of pipes and air is drawn through the soil pile. The system exhaust is passed through a carbon canister before discharge. This negative air pressure system is effective in both delivering oxygen into the soil pile's core and controlling air emissions of any volatile organics. An irrigation system will supply water and nutrients to the indigenous microbial populations. Any leachate is contained by a high-density liner, collected and recycled back through the irrigation system.

### Table 3

<table>
<thead>
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<th>Contaminant</th>
<th>Concentration (ppm)</th>
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<td>Total petroleum hydrocarbon (EPA Method 418.1)</td>
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<tr>
<td>Total petroleum hydrocarbon (EPA Method 8015 modified for diesel)</td>
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<tr>
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<td>Toluene</td>
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</tr>
<tr>
<td>Xylene</td>
<td>ND</td>
</tr>
<tr>
<td>Ethylbenzene</td>
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Table 3. Maximum soil contamination levels found in the soil stockpile at pipeline Site 1, the Port of LA.

### Table 4

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<td>Xylene</td>
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Table 4. Maximum soil contamination levels found in the initial site characterization at former tank farm Site 2., the Port of LA.

Although the treatability study is not complete, the Harbor Department estimates the total time required for the project, including all studies, system design, permitting, construction, treatment and closure, to be 48 weeks.

Since examination of the pipelines and an associated underground vault during removal did not implicate any one party, the three oil companies and the Harbor Department are currently negotiating to apportion the costs of remediation.

**Site 2, former tank farm**

The second remediation project underway at the Port, Site 2, is located at a former petroleum tank farm removed as part of the construction of a new cargo terminal. The facility, built in 1928, was operated by a number of companies, handling a variety of petroleum products. The operator of the facility during the last seven years handled marine diesel fuel, Bunker C fuel oil, and other fuel oils. In the planning of the cargo terminal, early consideration was given of the possibility of contamination at the site. As a consequence, the tenant undertook a site investigation in the early stages of project planning.
As with Site 1, the project was contaminated with petroleum hydrocarbon with associated BTXE (see Table 4, page 42). The total volume of contaminated soil at the site was a minimum of 15,000 cubic yards. In addition to soil contamination, there was free phase petroleum product in the shallow groundwater (five to 10 feet below grade) at the site. Four of the 18 wells at the site contained the free product. Two wells have three inches or less, one two-feet and the last, three feet. This product was identified as primarily gas-oil with a moderate percentage (2-45 percent) of lighter petroleum products. Based on the results of the investigation, the tenant classified the contaminated soil as a designated waste.

In first phase of remediation, the tenant began free product recovery while the final planning of the soil remediation at the site was underway. Consideration of waste stabilization was rejected when the treatability study failed. Excavation and disposal was rejected by the tenant because of expense and an in-situ bioremediation option was selected.

The remedial design called for a system of five parallel drain pipes at 14 to 20 feet below grade and spaced at 65 foot intervals installed across the site. A pump removes groundwater from the pipelines and discharges it into a oil-water separator. Once separated from the oil, the water has nutrients and hydrogen peroxide added, is pH balanced and then applied to the site.

Once permitted, the system became fully operational in late January 1990. During the operation of the system, soil samples were taken at three and six foot depths at 14 locations at the site. Close examination of the composition of the petroleum hydrocarbon revealed the chain length to be mostly C11 though C20. Therefore, starting May 16, 1990, the analytical methods used were changed to allow for better quantification of those petroleum hydrocarbons of concern to the permitting agency.

From January 17 through June 8, mean petroleum hydrocarbon concentrations in the soil dropped by one-eighth. In the percentage of samples above 1,000 ppm, the treatment goal, there was a decrease over time. Also, during treatment, BTXE levels had been reduced in most locations. After June 8, those areas with high petroleum hydrocarbon levels or where BTXE were present were excavated.

Soil sampling took place on June 28, after shutting off the treatment system and allowing the site to dry. Excluding those areas excavated which were not sampled, the mean petroleum hydrocarbon concentration was 3,043 ppm. Discounting the very high value found in one sample (31,160 ppm), the mean on June 28, was 1,561 ppm or 6,500 less than mean concentration on the starting date.

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