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Management and Problem-Solving for Environmental Professionals

SEPTEMBER 1997

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801 ❑ Stationary Mount Aerators
802 ❑ Submerged Aerators
803 ❑ Tube Aerators
804 ❑ Centrifugal Fans
805 ❑ Aeration Blowers
806 ❑ Aeration Systems
807 ❑ Axial Fans

B. What is your reason for purchasing the selected products/services? (Select one)

808 ❑ New Construction
809 ❑ Plant Upgrade
810 ❑ Replacement/Maintenance

C. What is your projected budget for the selected products/services? (Select one)

811 ❑ Over $200,000
812 ❑ $100,001-$200,000
813 ❑ $50,001-$100,000
814 ❑ $10,001-$50,000
815 ❑ $5,000-$10,000
816 ❑ Under $5,000

D. How immediate is your need for the selected products/services? (Select one)

817 ❑ 0-3 months
818 ❑ 4-6 months
819 ❑ 7-9 months
820 ❑ 10-12 months
821 ❑ over 12 months

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19	50	81	112	143	174	205	236	267	298	329	360	391	422	453	484
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23	54	85	116	147	178	209	240	271	302	333	364	395	426	457	488
24	55	86	117	148	179	210	241	272	303	334	365	396	427	458	489
25	56	87	118	149	180	211	242	273	304	335	366	397	428	459	490
26	57	88	119	150	181	212	243	274	305	336	367	398	429	460	491
27	58	89	120	151	182	213	244	275	306	337	368	399	430	461	492
28	59	90	121	152	183	214	245	276	307	338	369	400	431	462	493
29	60	91	122	153	184	215	246	277	308	339	370	401	432	463	494
30	61	92	123	154	185	216	247	278	309	340	371	402	433	464	495
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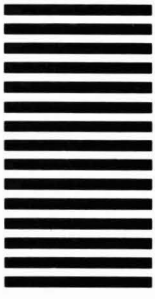

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About the cover:

Eliminating nitrogen from wastewater prior to discharge is necessary because it can impact the receiving water's quality. Significant nitrogen concentrations in treated effluent may, among other effects, be toxic to aquatic life, stimulate algae growth, hamper chlorine disinfection efficiency and present a public health hazard.

Bioaugmentation, the process of introducing bacteria like *Pseudomonas* into wastewater to reduce nitrogen levels through natural biological digestion, is increasingly being used in industrial and municipal wastewater treatment plants. The article beginning on page 16 profiles how one poultry processing plant successfully used bioaugmentation to overcome excessive ammonia levels in its effluent discharge.

Photo of Munox® Bacteria
Courtesy of Osprey Biotechnics

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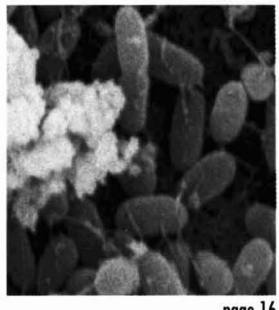
features



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The Rising Tide of Privatization

It started as a trickle. In the early 1990s, communities began looking at the private sector for help in improving the efficiency of their wastewater treatment plants' (WWTP) operations. Budget cuts, stricter regulatory demands, citizens' increasingly rebellious attitude toward higher taxes, private companies' push to handle the work, and the widespread perception that governmental employees tend to be less productive than private sector workers were all factors that encouraged this shift toward privatization.

Now WWTP privatization is beginning to surge throughout the United States. Taking three possible forms, private sector involvement can consist of either contract operations, leasing by the private party or the private party's outright purchase of the WWTP. By far, the most common arrangement is contract operations, in which the municipality hires a private party to run the WWTP and no funds are transferred from the private party to the municipality. In contrast, with a leasing arrangement, a private entity operates the WWTP and invests funds in the facility by paying lease payments to the municipality. Currently, this is gaining in popularity. The third variation, in which a private party buys the WWTP, is the rarest type of privatization. One example occurred in 1995 when Wheelabrator EOS purchased a WWTP from the city of Miami, Ohio, for $6.8 million.

The federal government's effort to promote WWTP privatization is having an impact on how communities structure their relationships with private entities. In the January 16, 1997 *Federal Register,* the U.S. Internal Revenue Service published a new tax rule that allows communities to enter into operational management contracts pertaining to WWTPs for up to 20 years without threatening the tax-exempt status of outstanding municipal debt. The new rule is prompting more municipalities to opt for contract management arrangements rather than selling their WWTPs to private entities.

The federal government's role in this seemingly local issue stems from the fact that the U.S. Environmental Protection Agency has been bankrolling municipal wastewater treatment for the past 25 years. During this period, the EPA has invested about $65 billion in large municipal WWTPs (plants with at least 1 million gallons per day capacity).

As part of its involvement with communities' wastewater treatment, the EPA is starting to actively promote privatization. Recently, the agency established a privatization coordinator within the Office of Wastewater Management to speed up the approval of privatization agreements (Haig Farmer with the EPA's Municipal Support Division at 202-260-7279 can provide additional information about the EPA's policies in this area).

The growing number of success stories illustrates the advantages of privatizing WWTPs. For example, a case study in this issue, which begins on page 28, profiles a public-private collaboration in Kenner, La., that improved services for residents and reduced the WWTP's costs for operation, maintenance and management.

Taxpayers' pocketbooks and the environment can profit from this new trend. Increased efficiency of plant operations, better compliance with tougher water quality standards, lower operating expenses and access to private sector capital are important benefits that communities can gain by working with private companies.

Angela Neville

Angela Neville, JD, REM
Editor, *Environmental Protection*

Environmental PROTECTION

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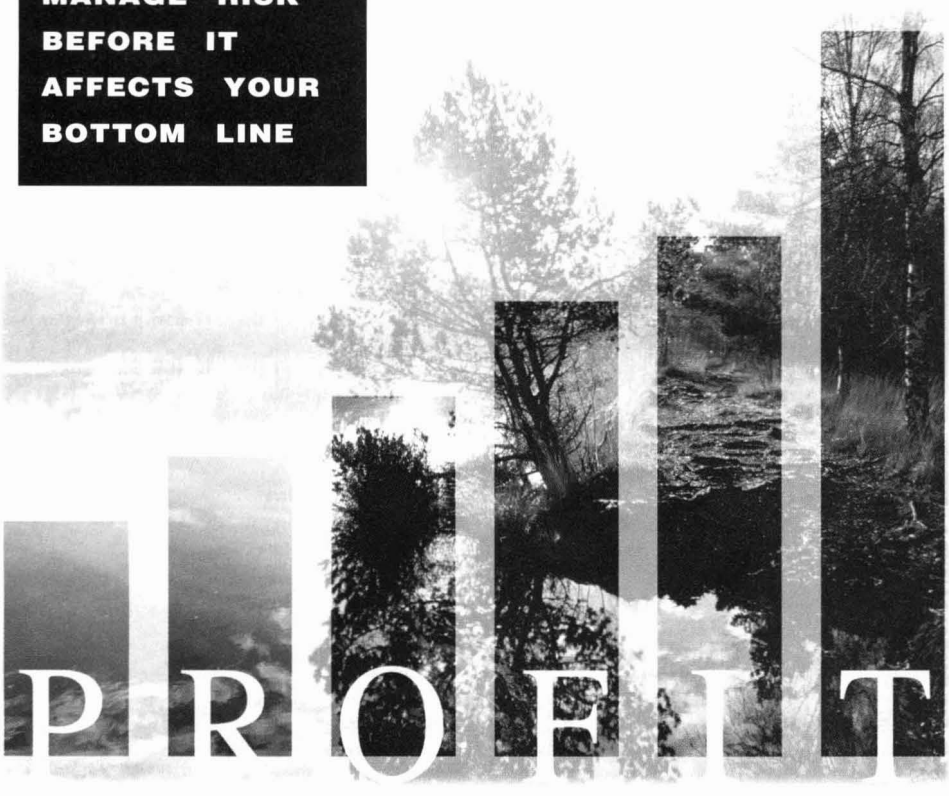

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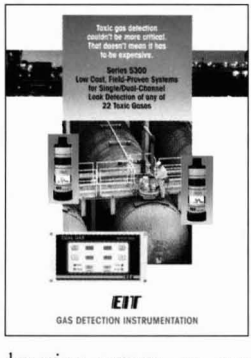
Leak Detection

Bulletin

EIT published a product bulletin on its Series 5300 leak



detection systems—an economical alternative for sites that do not require monitoring of gas concentration levels. Each piece of equipment in a typical 5300 system is profiled in the bulletin. **EIT.**
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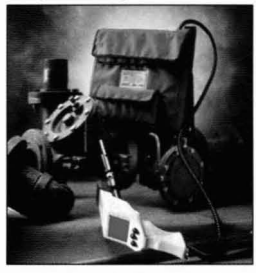
Portable FID

The Model 680 HVM is a fully integrated fugitive emissions



monitoring solution. The three-key interface is ideal for fugitive emissions, hazwaste, spill response and industrial hygiene monitoring. It integrates a highly sensitive flame ionization detector, data logger and optional laser bar code scanner. **Thermo Environmental Instruments Inc.**
Circle 181 on card.

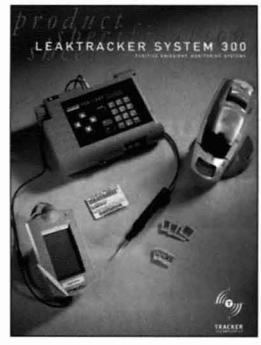
Gas Detection System

The MIRAN SapphIRe series comes in a lighter, smaller

and less-expensive package. Fugitive volatile organic chemicals can be detected in process applications for worker safety and industrial hygiene studies. The long pathlength infrared optical bench also allows detection of inorganic chemicals and a variety of semiconductor gases. The on-board datalogging feature is ideal for HVAC studies, indoor air quality studies and quasi-continuous monitoring. **Foxboro.**
Circle 182 on card.

Emissions Monitoring Systems

The Leaktracker System 300 is a complete system to integrate leak detection and repair. Monitoring data can be used for permanent records. Features



include a detachable lightweight probe for hard-to-reach places and a pen-based computer. **Tracker Technologies Inc.**
Circle 183 on card.

Gas and Oxygen Monitor

The Model 3802 infrared gas and oxygen monitor uses photo-acoustic infrared technology to monitor a variety of infrared active gases including carbon monoxide, hydrocarbons, solvents, alcohols, alkanes and other toxic gases along with oxygen. All readings are visible on a front-panel display with alarms and diagnostic messages. **MSA Instrument Division.**
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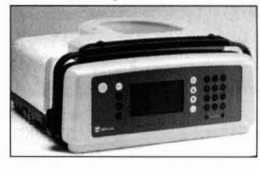

analysis of volatile organic compounds. It is battery-powered, lightweight and weatherproof and can determine and quantify VOCs in minutes. Endures harsh testing environments, rough handling and shocks typical of field work. **Inficon.**
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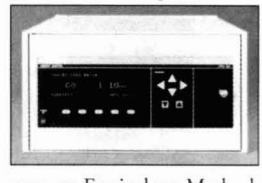

ence or Equivalent Methods in accordance with 40 CFR 50-53. It includes CO monitor, NO-NO_2-NO_x monitor, SO_2 monitor, O_3 monitor and CH_4-NMHC-THC monitor. **Horiba Instruments Inc.**
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The Quadrants portable gas detector is small, lightweight and inexpensive. Surface-mount electronics and flexibility in sensor combinations allows customization to meet specific requirements. **ENMET Corp.**
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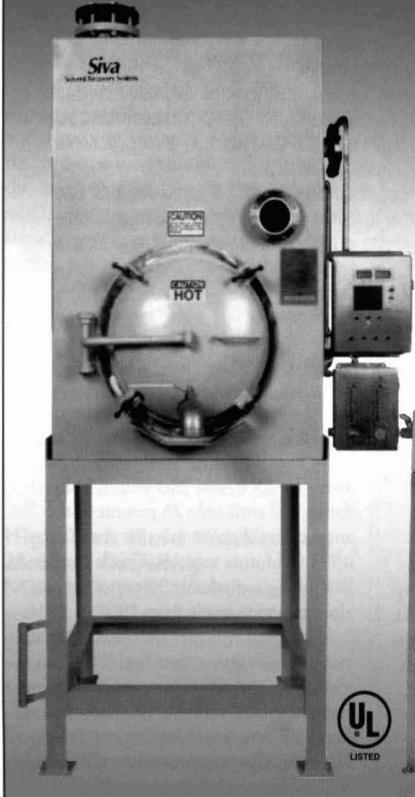

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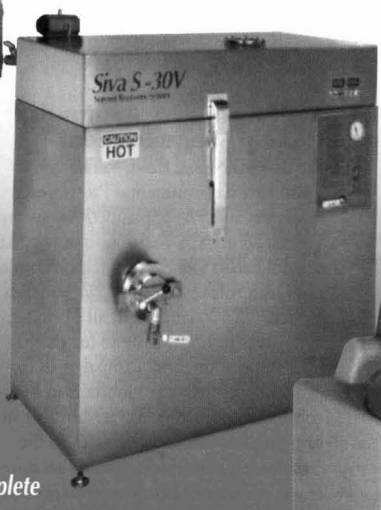

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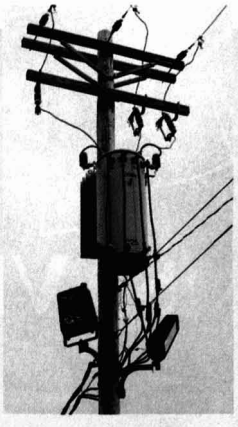
EPA Introduces Transformer Program



WASHINGTON, D.C.— As competition among utility companies grows, so do the technological advances through which they can provide cost-effective electricity while reducing air pollution emissions and staying profitable. High-efficiency distribution transformers are one way a utility can maximize both efficiency and profitability.

The U.S. Environmental Protection Agency saw transformers as a vehicle for efficiency and pollution prevention and created the Energy Star® Transformer Program. The program recognizes and supports utility companies that purchase and install high-efficiency distribution transformers through cost savings and environmental recognition. This voluntary, non-regulatory pollution prevention program enables utilities to efficiently distribute electricity while aiding in the reduction of air pollution by reducing air emissions associated with transformer losses.

More than 61 billion kilowatt-hours of electricity—almost 2 percent of U.S. electricity production—are lost annually due to inefficient transformers. To replace these energy losses, all electric generating plants in the United States would have to operate for an additional eight days.

Efficiency targets for the Energy Star Transformer Program are designed so that roughly 35 percent of the transformers sold to utilities in 1994 would have qualified for the Energy Star designation.

The Energy Star Transformer Program is completely voluntary. The EPA has no legislative authority to mandate the purchases of high-efficiency transformers by utilities.

California EPA Applauds Honda Announcement

SACRAMENTO, Calif.—The California Environmental Protection Agency (Cal EPA) applauded American Honda Motor Co.'s announcement that it would sell 1998 Accord vehicles meeting California's stringent Low Emission Vehicle (LEV) standard in all 50 states.

"This is heartening news for the nation and our ongoing campaign to improve air quality, and Honda is to be commended for their leadership role in bringing low-emission vehicles to the consumer. California's clean air technology is once again being exported to the rest of the country," said Peter M. Rooney, the EPA's acting secretary for environmental protection.

California's LEV program established stringent emission standards for nonmethane organic gas (NMOG), oxides of nitrogen (NO_x) and carbon monoxide (CO) for four new classes of low-emission vehicles, according to Rooney. So far, the standards have proven to be effective—by 2000, new cars sold in California will emit only 25 percent of the most harmful pollutants that come from 1993 California vehicles. This is in addition to the remarkable 90-percent emission reduction made from 1966 to 1994.

"California will gain additional benefits not just with our in-state fleet, but from visitors and new residents who are driving these new LEV vehicles. The nation gains because of our world-leading standards. We encourage other auto manufacturers to join the parade," Rooney said.

State Office of Marine Safety Merges With Ecology

OLYMPIA, Wash.—Effective July 1, the state Office of Marine Safety (OMS) merged with the Department of Ecology to form a new comprehensive spill prevention, preparedness and response program. The merger combines OMS' marine vessel safety and oil spill prevention activities with Ecology's facility oil spill prevention and statewide oil and hazardous material response and restoration program.

The "Spill Prevention, Preparedness and Response Program" will be comprised of about 55 staff members, including spill responders, vessel inspectors, environmental planners, engineers and other management and support staff.

After the 1988 *Nestucca* oil spill off Grays Harbor County and the 1991 Exxon *Valdez* spill in Alaska, Washington citizens demanded that the state establish a higher level of protection than that which existed at the time. In 1991, the state legislature established the independent marine safety office and Ecology's spill program. Under this original law, OMS was slated to fold its activities into Ecology in 1997.

According to Prevention Section Manager Stan Norman, the vessel safety and inspection program will continue under the new organization. "Through the merger, we will actually strengthen and improve our ability to prevent oil transfer spills at marine terminals. Now when we look at spill prevention, we will be able to do so with a unified vision and program." Ecology will maintain its geographic service delivery through marine safety field offices in Seattle and on the Columbia, and will keep its current spill preparedness and 24-hour spill response capability at the agency's four regional offices in Bellevue, Lacey, Spokane and Yakima.

High-Tech Fluid Purification Market Growing

NORTHBROOK, Ill.—In less than 15 years, the world market for purification of air, gases and liquids in high-technology industries has grown from less than $.5 billion to more than $9 billion per year. According to a series of forecasts by the McIlvaine Co., the double-digit growth will continue over the next five years to create a $15 billion per year market by the year 2000.

The growth in the high-tech purification markets has coincided with the shrinkage of traditional markets, especially in developed countries. For example, electrostatic precipitators for air pollution control were first applied to cement kilns about 80 years ago. The major applications for purification of liquids were basic chemicals, mining and food products. Developed countries have now taken over much of this activity, so high-tech industries in western Europe, Japan and the United States now comprise a market segment as big as traditional markets.

High-technology industries are defined as pharmaceutical, biotechnology, semiconductor and other electronic segments.

Phytoremediation Markets Estimated

NEEDHAM, Mass.—The first published estimates of the market size for phytoremediation in the United States and its growth potential were presented in June at the International Business Communication's Second Annual International Phytoremediation Conference in Seattle, Wash.

The market estimates were presented by David J. Glass, PhD, of Glass Associates Inc. Dr. Glass estimated that the current U.S. market for phytoremediation is $3 to $7 million, of which $2 to $3 million was attributed to removal of organic contaminants from ground-

water and $1 to $2 million arose from removal of heavy metals from soils.

Although groundwater phytoremediation is the largest and best-established segment of the market, Dr. Glass estimates that the markets for metal and radionuclide cleanup are capable of more dramatic growth due to the larger revenue than can be expected per site on such projects. He estimated the overall U.S. phytoremediation market will grow to $24 to $50 million by the year 2000.

Phytoremediation is the use of plants, including grasses and trees, to remove, degrade or sequester hazardous materials from contaminated media such as soil or groundwater.

State Proceeds Donated

BATON ROUGE, La.—Under a new law, all proceeds from the current tax on hazardous waste disposal will soon go to the Louisiana Hazardous Waste Site Cleanup Fund. The fund, administered by the Louisiana Department of Environmental Quality (DEQ), is used to clean up abandoned hazardous waste sites for which potentially responsible parties cannot be found. Presently, only 25 percent of the tax revenue collected is dedicated to the fund, and the remainder is placed in the state's general appropriations fund.

The legislation, sponsored by Rep. Daniel Flavin, (R-Lake Charles), was signed by Governor Mike Foster on July 10. The changes will take effect July 1, 1998.

"This legislation will enable DEQ to pursue the cleanup of abandoned hazardous waste sites more aggressively," said DEQ Secretary J. Dale Givens. "These additional funds will also give the agency more flexibility in investigating contaminated sites across Louisiana in an effort to identify potentially responsible parties. By identifying the companies or individuals who disposed of the waste, we may be able to recoup full or partial cleanup costs."

The new law also raises the cap on the Hazardous Waste Site Cleanup Fund from the current $4 million to $6 million. According to the state Revenue Estimating Conference, $5.8 million is the current official forecast for proceeds of the hazardous waste disposal tax.

ASTM's Guides For Septic Systems

WEST CONSHOHOCKEN, Pa.—The critical need for reliable technical guidelines affecting on-site septic and other wastewater systems is being met with a series of new standards being developed by the American Society for Testing and Materials (ASTM).

Already released are standard guides for surface and subsurface site characterizations as well as for the preliminary sizing and delineation of soil absorption fields. ASTM also expects to publish in 1998 standards on the operation, maintenance and monitoring of septic systems, and has begun working on additional standard guidelines in the following areas: selecting on-site septic systems, setting treatment standards, evaluating existing systems, and decommissioning.

Long neglected when it came to comprehensive science-based guidance, on-site wastewater systems are nevertheless critical to safeguarding the nation's

groundwater supplies because they are used to treat 25 percent to 33 percent of all U.S. domestic sewage. While strict state and federal regulations govern large municipal wastewater disposal systems, on-site systems are largely controlled at the county level.

The new ASTM standards are voluntary and were developed with the help of grants provided by the U.S. Environmental Protection Agency, the U.S. Geological Survey and the U.S. Navy.

EPA Awards Grants To Reinvent Environmental Reporting

WASHINGTON, D.C.—As part of the Clinton administration's ongoing efforts to reinvent government, U.S. Environmental Protection Agency Administrator Carol M. Browner announced that eight states will be awarded grants of $500,000 each to assist in developing a system for "one-stop" reporting of environmental information.

Through these grants, the EPA is working in partnership with states to replace costly, paper-intensive environmental reporting with Internet sites that will provide easier access to more reliable information for citizens, industry, business and regulators at the federal, state and local levels.

The eight states receiving the grants are: Pennsylvania, West Virginia, Georgia, Mississippi, Minnesota, Texas, New Mexico and Oregon.

In 1996, five states—Massachusetts, New Jersey, Missouri, Utah and Washington—received $500,000 awards to assist in developing one-stop reporting systems.

U.S. Chamber Blasts New EPA Regs

WASHINGTON, D.C.—The U.S. Chamber of Commerce blasted the U.S. Environmental Protection Agency and Vice President Gore on July 16 for proceeding with new air quality regulations that ignore science, economics and the opposition of hundreds of mayors, governors, senators and U.S. representatives from both parties across the country.

"These new air quality standards are a travesty," said Dr. Harvey Alter, Chamber manager of resources policy. "They will hurt, not help, the American public. These standards are about selling a political agenda in an empty green bag and that will waste billions of dollars, and cost jobs and economic growth across America."

The Chamber's analysis of the EPA's economic calculations shows that benefits are excessively overstated and costs are understated. One reason is that neither the EPA nor anyone else knows how to meet the newly proposed standards. The Clinton administration's view seems to be that someone will figure it out and pay whatever it costs, sometime in the future.

Alter concluded, "There are miles of expensive, underused carpool lanes that people think are a waste of money. While sparse, traffic backs up in other lanes, cars idle, and tailpipe emissions

(Continued on page 52)

the grapevine

ITC Industrials, an affiliated company of Baltimore, Md.-based ITC Inc., acquired the "Gel Clay Assets" of the Floridin Co. formerly owned by U.S. Borax Co.

DuPont chose EHS/LifeCycle software system from EIS International Corp. as its waste management software package in facilities across the nation.

Johnston Construction Co. and **Remediation Inc.** merged to maximize both companies' assets while minimizing overhead.

The Whitman Companies Inc. added environmental, health and safety consultant Thomas W. Peter to direct its new industrial hygiene department.

Eastman Chemical Co. produces methanol from coal-derived synthesis gas at a commercial-scale demonstration facility using Air Products and Chemical Inc.'s patented liquid phase technology.

StoneHill Environmental Inc. of Portsmouth, N.H., an environmental consulting firm providing site assessment, litigation, remediation, wetlands and Massachusetts Licensed Site Professional consulting services, announced the addition of W. Gardner Warr.

Alfa Laval Separation Inc., Environmental Group, named M&C Associates to be its Mid-Atlantic region representative in the sale of Sharples decanter centrifuges.

The United Parcel Service was presented a Clean Air Award by California's Coalition for Clean Air in recognition of the company's initiative to convert a major portion of its delivery fleet to clean-burning compressed natural gas.

Charley Chambers joined the Kansas City, Mo., office of **Hanson-Wilson Inc.,** an engineering firm serving the railroad industry.

EIS International merged with EnviroMetrics to form **Essential Technologies Inc.**

Matheson Gas Products announced a re-emphasis on the production and supply capabilities for pure sodium brick and sodium dispersions, which it has manufactured for more than 20 years.

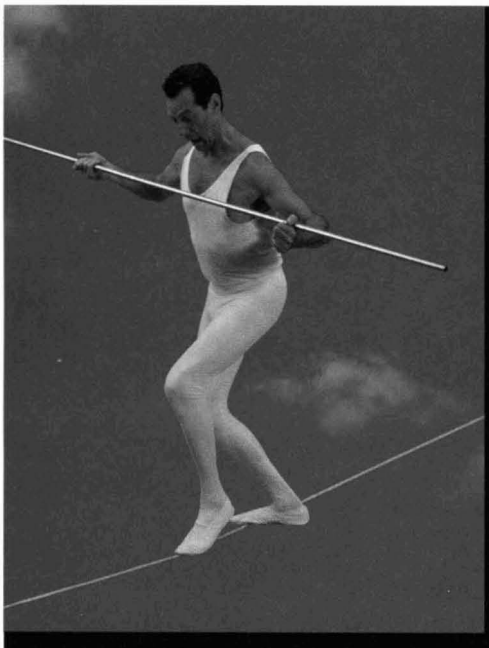
Dennis W. Petersen was promoted to the position of president of **Lockwood, Andrews & Newnam Inc.**

The Purolite Co., an international manufacturer of ion exchange resins, opened an office in Taipei, Taiwan. The office will be managed by Jason Lin and will serve all of Taiwan.

The Compressed Gas Association awarded the Bulk Fleet Safety award to BOC Gases for the fourth time in the last five years.

Foster Wheeler Environmental Corp. was awarded an $11 million contract by the U.S. Army Corps of Engineers Sacramento District to provide Base Realignment and Closure (BRAC) environmental services.

Dr. Edgar Berkley, president for the **Center for Hazardous Materials Research,** was appointed to the EPA's Science Advisory Board, to serve on the environmental engineering committee and advise the administrator. EP



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Ammonia Reduction Through Bioaugmentation

Specially selected microorganisms combine organic carbon digestion with inorganic nitrogen removal in a single step during wastewater treatment.

By Hiren K. Trivedi, MSChE

Clean water is a priority in our industrialized society. There is an ever increasing need to process and purify water from industrial operations and municipal sources prior to discharging into natural water systems. Activated sludge wastewater treatment plants have been widely used to address this problem.

Wastewater treatment is one of the earliest large-scale applications of biotechnology. It differs from other industrial microbiological processes in that there is little or no control over the raw material and only moderate control over the operation conditions, yet the process is expected to produce a uniform finished product. The goals of the process normally include the removal of organic pollutants and nutrients (i.e. nitrogen and phosphorous) before discharge.

Removal of nitrogenous compounds is critical as excessive ammonia and nitrite/nitrate levels are detrimental to water quality. Ammonia exerts an oxygen demand in aquatic environments; 4.7 grams of oxygen are required to oxidize one gram of ammonia. Nitrite is toxic to marine life and can induce methemoglobinemia (a reduction in the oxygen-carrying capacity of the blood) in humans. These factors call for effective removal of nitrogen from the wastewater before it is discharged to natural water systems. Poultry and meat processing plants, food processing plants and refineries are constantly facing this challenge of being in compliance for ammonia discharge in the wastewater.

Photo courtesy of Osprey Biotechnics

Wastewater treatment plant.

A Reoccurring Problem

A large poultry processing plant in the United States had a reoccurring problem of excessive ammonia levels in its effluent discharge due to plant operations. Daily wastewater flow to the plant is 0.85 million gallons. Typical inlet ammonia levels are 80 to 120 parts per million (ppm) as nitrogen.

The influent, after primary treatment and flow equalization, flows into a 7.5-million gallon anaerobic lagoon followed by a series of three 0.6-million gallon aerated lagoons. The wastewater is then fed to four sequencing batch reactors (SBRs). At the end of the settling cycle the decanted supernatant—the top, treated water layer—is discharged to a creek. Because the plant had trouble keeping the supernatant treated water quality uniform it had to struggle to meet the discharge limits based on problems with the elevated ammonia concentrations.

After several techniques for ammonia removal proved unsuccessful, the plant opted for bioaugmentation with Munox®, a safe, patented freeze-dried bacterial product capable of reducing the nitrogen levels (ammonia, nitrite and nitrate) through natural biological digestion. Initial seeding was done in the aeration basin as well as in the SBRs. The commercially available microbial product is comprised of naturally occurring and non-pathogenic strains of *Pseudomonas* bacteria with exceptional ca-

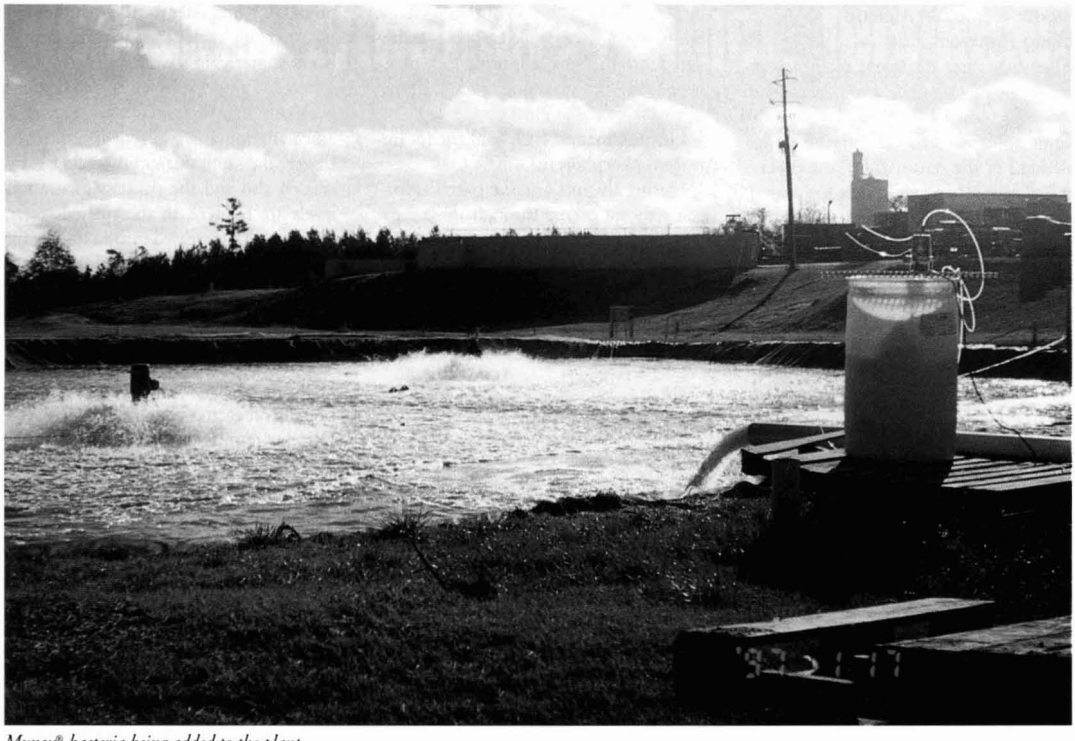

Photo courtesy of Osprey Biotechnics

Munox® bacteria being added to the plant.

pabilities of metabolizing stubborn organic compounds. The end products are harmless carbon dioxide (CO_2) and water; no toxic intermediates are left behind in the system.

These specially selected microorganisms consume a wide range of organic substrates efficiently. This results in an increased carbon uptake and consequently, an increased nutrient uptake, so their ammonia uptake as a nitrogen source (nutrient for growth) is higher than that for the naturally occurring microbial population in the activated sludge system. Further, they are capable of utilizing nitrite and nitrate for respiration (denitrification) as well as for growth as nitrogen sources. Hence, bioaugmentation with *Pseudomonas* results in immediate reduction in ammonia-nitrogen levels combined with a more efficient carbonaceous biochemical oxygen demand (BOD) removal **in the same reactor.**

Bioaugmentation Solves The Problem

The food processing plant saw a 40-percent ammonia reduction in 48 hours and the effluent discharge fall below compliance levels. Subsequent constant inoculation with Munox has kept the outlet water quality uniform and the high ammonia problem has been resolved cost effectively. The plant started the bioaugmentation program in summer of 1996 and has not exceeded the ammonia discharge limits since, even under **cold weather conditions.**

Conventional Approach to Ammonia Removal

The conventional approach to ammonia removal only converts one form of nitrogen (ammonia) to another (nitrite or nitrate).

The conventional method of removing nitrogen from wastewater starts with oxidation of ammonia to nitrite/nitrate (nitrification) and ends with reduction of nitrite and nitrate to nitrogen gas (denitrification).

Nitrogen exists in wastewater in four different forms:

- Organic nitrogen (amino acids, proteins, purines, pyrimidines, and nucleic acids);
- Ammonia nitrogen (NH_3-N);
- Nitrite nitrogen (NO_2-N); and
- Nitrate nitrogen (NO_3-N).

In an untreated wastewater sample, the major fraction is usually ammonia nitrogen and the organic nitrogen. These are oxidized to nitrite and then to nitrate in the environment. Biological nitrification, a two-step process, begins with ammonia being converted to nitrite by *Nitrosomonas* bacteria, followed by nitrite being oxidized to nitrate by *Nitrobacter* bacteria. These bacterial species are typical examples for the nitrification process. They are autotrophic in nature and use carbon dioxide as their cell carbon source.

NH_4^+-N + $^3/_2O_2$ = NO_2^- + $2H^+$ + H_2O (*Nitrosomonas*)

NO_2^- + $^1/_2O_2$ = NO_3^- (*Nitrobacter*)

This process usually requires long mean cell retention time (MCRT) of up to few days and hence, huge tank volumes. It is very sensitive to cold temperatures as well as the presence of toxic chemicals in the system. The rate of nitrification slows down significantly during colder weather.

The nitrite and nitrate is subsequently reduced to nitrogen gas by denitrification process as follows:

NO_3^- + $2e^-$ + $2H^+$ = NO_2^- + H_2O

NO_2^- + e^- + H^+ = NO + OH^-

2NO + $2e^-$ + $2H^+$ = N_2O + H_2O

N_2O + $2e^-$ + $2H^+$ = N_2 + H_2O

Bioaugmentation Method Using *Pseudomonas*

The wastewater treatment plant was relying on the ammonia nitrification step to convert ammonia to nitrate using the autotrophic bacteria as explained earlier. Because of the sensitivity of the process it had reoccurring violations for ammonia discharge and hence, they opted for bioaugmentation with Munox. The *Pseudomonas* bacteria used in these products are heterotrophic and utilize organic carbon as the source for food and energy. First, the organic matter is oxidized by bacterial cells to obtain energy. Simultaneously, organic carbon is assimilated into the new cells using the energy produced with ammonia as a preferred nitrogen source in most cases.

Organic matter + O_2 + nutrients (nitrogen, phosphorous) = new cells

During this process the overall nitrogen removal occurs through three separate mechanisms.

1) The specially selected *Pseudomonas* strains are very efficient organic degraders and also have a wider organic substrate range (including many toxic compounds). Consequently, their carbon uptake is much higher than what is normally encountered in a wastewater treatment system. With a higher carbon uptake the nutrient requirement is also increased. Since ammonia is available as a nitrogen source, the ammonia consumption is increased also and the discharge ammonia levels are reduced in the treated water. Further, with increased carbon uptake the BOD—as well as the chemical oxygen demand (COD)—discharge levels drop below the normal values, resulting in an increased operational efficiency.

2) *Pseudomonas* bacteria are considered one of the most active denitrifiers present on earth. They utilize nitrite/nitrate for respiration if the dissolved oxygen drops below the critical level in the aeration tank. Even in a completely mixed stirred tank reactor, low dissolved oxygen concentrations are commonly found. This also results in ammonia removal since some of it does get converted to nitrite and nitrate due to the naturally occurring autotrophic bacterial population. Just like oxygen, denitrification allows a complete oxidation of organic substrate to CO_2 and water.

3) The third mechanism involves the use of nitrite and nitrate as nutrient sources during the assimilation process. Laboratory studies on these products have revealed that they are capable of utilizing nitrite as well as nitrate for growth purposes if ammonia is no longer available in the system.

Conclusion

Similar results have been seen in poultry and meat processing plants as well as in petroleum refinery applications. The specially selected strains of *Pseudomonas,* capable of efficient ammonia removal coupled with natural digestion of toxic organic compounds, provide industrial and municipal wastewater treatment plants a cost-effective solution to a common problem. Bioaugmentation with Munox bacteria results in removal of nitrogen from the wastewater rather than a conversion of one form of nitrogen (e.g. ammonia) to another form (nitrite or nitrate). Munox products are safe to handle and non-pathogenic to humans. EP

Hiren Trivedi, MSChE, is an engineering manager with Osprey Biotechnics, Sarasota, Fla.

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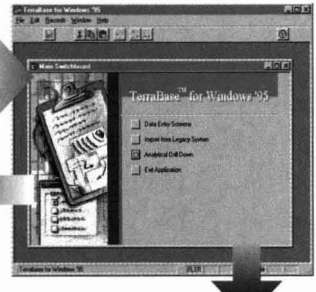

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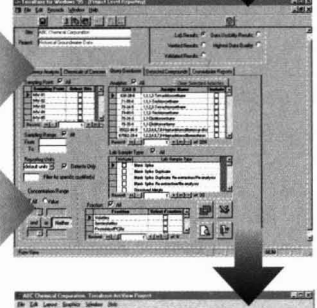

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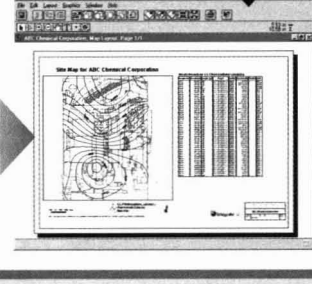

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P2

Special Report

Pollution Prevention Planning

P2 tactics can lead the way to successful strategic environmental management.

By Robert M. Abbott

The past 30 years have seen an evolution, if not a revolution, in perceptions and attitudes toward the environment. The discipline of environmental management is scarcely more than 30 years old; its roots can be traced to the late 1960s and the birth of the modern environmental movement.

Passage of legislation such as the National Environmental Policy Act in 1969 focused attention on environmental assessment of large projects and the control of pollutants at the source of discharge. Later, two of the more prominent examples, the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Cleanup and Liability Act, galvanized action on specific environmental concerns.

In the 1990s, societal concern about planetary health, a growing corporate awareness and acceptance of environment-economy linkages, and the deliberations of numerous national and international conferences have introduced new language to the environmental debate, notably the concept of strategic environmental management (SEM).

SEM is an "umbrella" term used to connote the long-term sustainable advantage that can flow from proactive responses to environmental issues or pressures. Essentially, it suggests that a measurable business benefit results from integrating environmental issues into business planning and strategic planning.

This ideological growth has ushered in a new suite of environmental management standards, ideas and approaches. Among the more prominent are notions of environmental management systems (EMS) and pollution prevention (P2) planning.

The concept of EMS, and the specific requirements of the International Organization for Standardization (ISO) 14001 EMS standard, have been heavily discussed. Similarly, there is a rapidly expanding body of literature in the realm of P2. However, the published record does not consistently make clear the strong relationship between the two topics. Pollution prevention should be an integral part of an EMS; it is not a separate system.

Notwithstanding the growth in general environmental awareness over the past 30 years, it is often difficult to convince an organization to adopt EMS and/or SEM. However, several tangible benefits are associated with P2, including a reduction in raw material consumption, reduced production costs, reduced energy costs and reduced waste generation. These benefits make P2 an easy first step and a powerful lever for broader EMS and SEM activities.

Pollution prevention targets the root cause(s) of pollution and seeks to reduce or remove pollution at the source, eliminating the transfer of risk from one environmental medium to another. Consequently, it is a more comprehensive strategy for environmental management or protection than earlier pollution "control" efforts.

The notion of strategy is important because P2 cannot exist without it. Many organizations try to improve or even "optimize" performance in waste management or water quality, but these functional efforts do not embody P2. They reflect an earnest,

but ultimately myopic view that by improving performance on individual environmental issues, overall corporate environmental performance will improve.

However, this is not necessarily the case. Small improvements might be observed, but unless the organization looks at the process relationships that exist (or might exist) between those issues, and thinks of new processes and new ways of conducting business that eliminate the issues, substantive improvements in performance will not be achieved. P2 requires changes in the way an organization thinks about technology and process, the level and type of responsibility delegated to employees, the criteria used to measure performance, and corporate governance.

Such changes are impossible without a strategy that sees beyond the success of current methods to different and more creative alternatives. No less an authority than sir Francis Bacon captured the spirit of what is needed when he observed that "...to achieve results never before accomplished, we must expect methods never before attempted." The conceptual framework for P2 is shown in **Figure 1.**

There are at least three striking features of this framework. The first is its systemic nature or its insistence on creating a plan in which a set of connected things work together (organizational structure, responsibilities, practices, procedures, processes and resources). The second is the similarity between this framework and the elements of an EMS (purpose, commitment, capability and learning). Most importantly, P2 should be considered at a company-wide rather than departmental level, and as such, is a team exercise requiring cross-disciplinary skills. The way in which these skills might be "packaged" to put P2 into action is shown in **Figure 2.**

Besides putting P2 into action, the packaging of cross-disciplinary skills in support of broadly substantive environmental change within an organization is, if not the essence of SEM, an important step along the way. People who might not ordinarily work together begin talking about a common goal that transcends departmental boundaries. This dialogue becomes a way of removing the infamous "green walls" that frequently impede environmental initiatives because it identifies opportunities to lever off well-established and effective company practices.

If P2 can be merged with existing safety and health programs, for example, an existing management system is put to further use and the stigma of creating "another manual or program" is avoided. The P2 process, particularly the identification and evaluation of opportunities, is rooted in economic evaluation—the economic feasibility of these opportunities needs to be assessed using one or more of cost-benefit analysis, point factor analysis, average cost models or marginal cost models. As a result, it effectively translates an environmental issue

Figure 1 – Conceptual Framework for Pollution Prevention

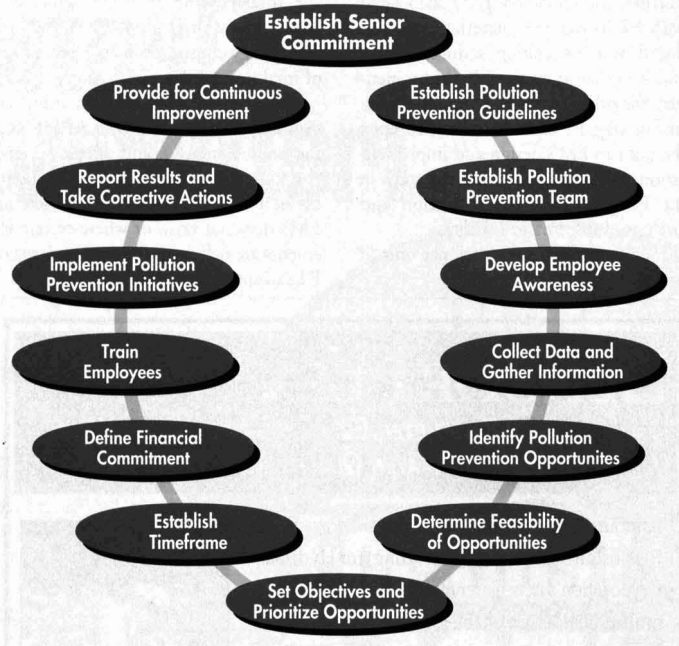
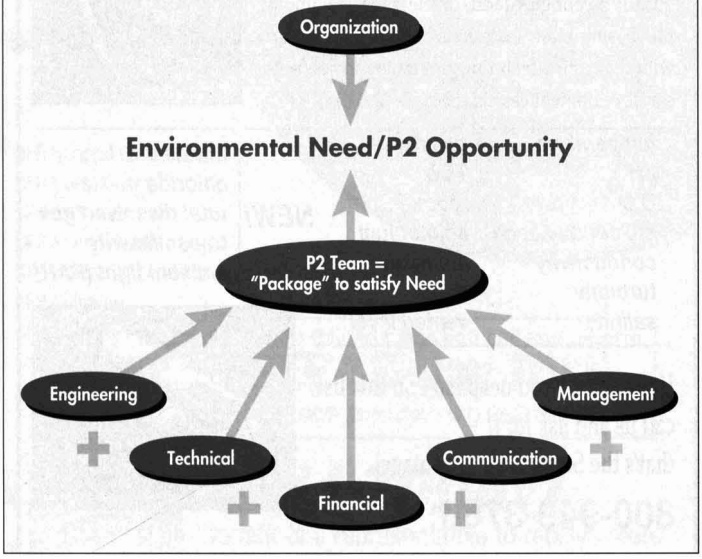


Figure 2 – Packaging Complementary Skills for Pollution Prevention



into language that has resonance for financial and management personnel. Further, the efficiency gains associated with P2 (better raw material usage, reduced waste generation, reduced energy and water consumption) build momentum for other environmental initiatives. In this way, P2 becomes a lever to open the door to EMS design and implementation. For example, one of the steps in the P2 process is the collection and analysis of information such as:

- emission of a substance per unit of production;
- raw material usage per unit of production;
- total volume or weight of all discharges per unit of production; and
- energy consumption as a percentage of total unit cost of production.

The accumulation of such information is accommodated by an EMS (i.e. the implementation and operation, and checking and corrective action elements of the ISO 14001 standard). Where an EMS does not exist, or where certain elements are deficient, the requirements of P2 can spur its creation.

In the case of organizations pursuing ISO 14001 registration, P2 is an explicit requirement—something to be embodied in the environmental policy and operating procedures at a working level.

Another increasingly prevalent view is that many organizations find the prospect of implementing an EMS daunting and want to break the process into "chewable chunks." Pollution prevention can often be positioned as a first step toward EMS and, if economic benefits are realized, additional EMS "chunks" can be undertaken.

Notwithstanding the growth in general environmental awareness over the past 30 years, it is often difficult to convince an organization to adopt EMS and/or SEM.

Ultimately, it doesn't matter *how* an organization implements P2, EMS or SEM. The important questions are *why* and *why not.* To answer those questions is to confront our changing perceptions and attitudes toward the environment. Acknowledging that the root cause of many environmental problems can be traced to systematic failures of one type or another. The emergence of EMS thinking implicitly, if not explicitly, raises the strategic profile of environmental management by asking corporations to establish internal controls for environmental planning that echo those for business, financial and strategic planning. As an exemplar of this thinking, P2 holds considerable promise, in its own right and as a catalyst for the ideological changes necessary for EMS and SEM. As to the how, it "...is not the frame which is important but what is framed." EP

Robert Abbott specializes in strategic environmental management. Over the past decade, he has worked with many of North America's largest private and public corporations to integrate environmental management considerations with business planning and strategic planning processes.

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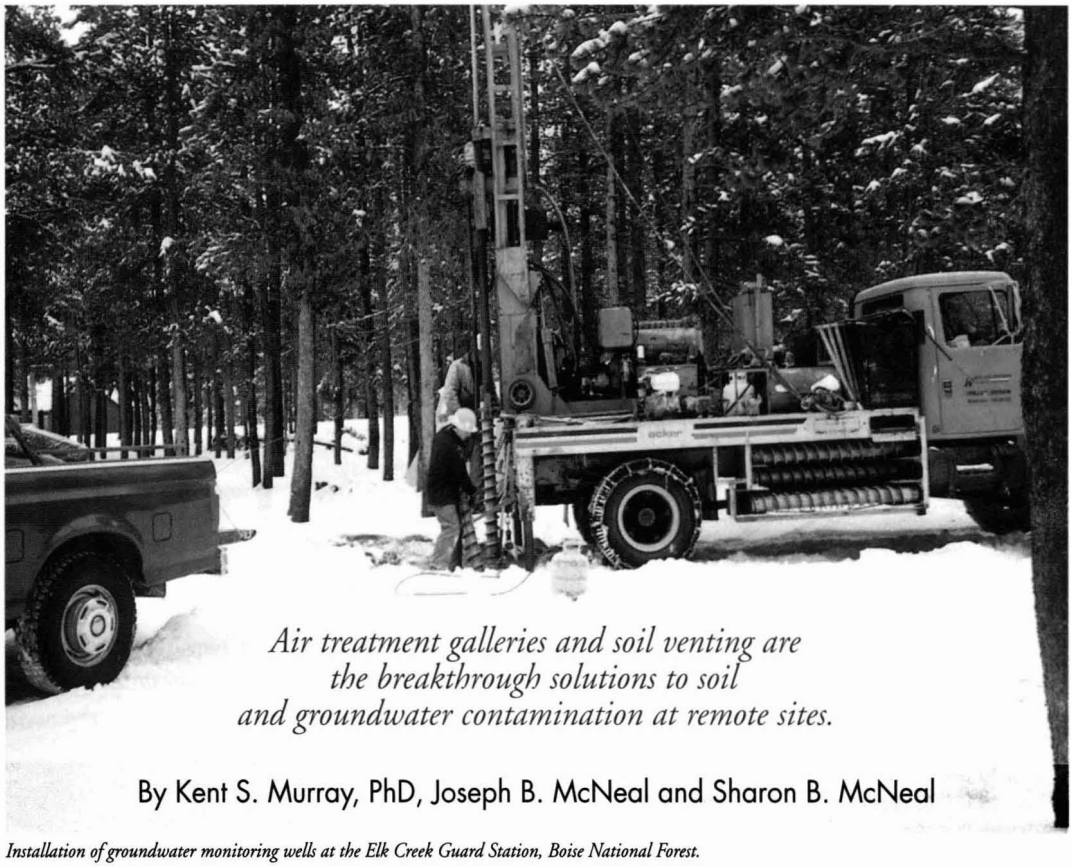


Air treatment galleries and soil venting are the breakthrough solutions to soil and groundwater contamination at remote sites.

By Kent S. Murray, PhD, Joseph B. McNeal and Sharon B. McNeal

Installation of groundwater monitoring wells at the Elk Creek Guard Station, Boise National Forest.

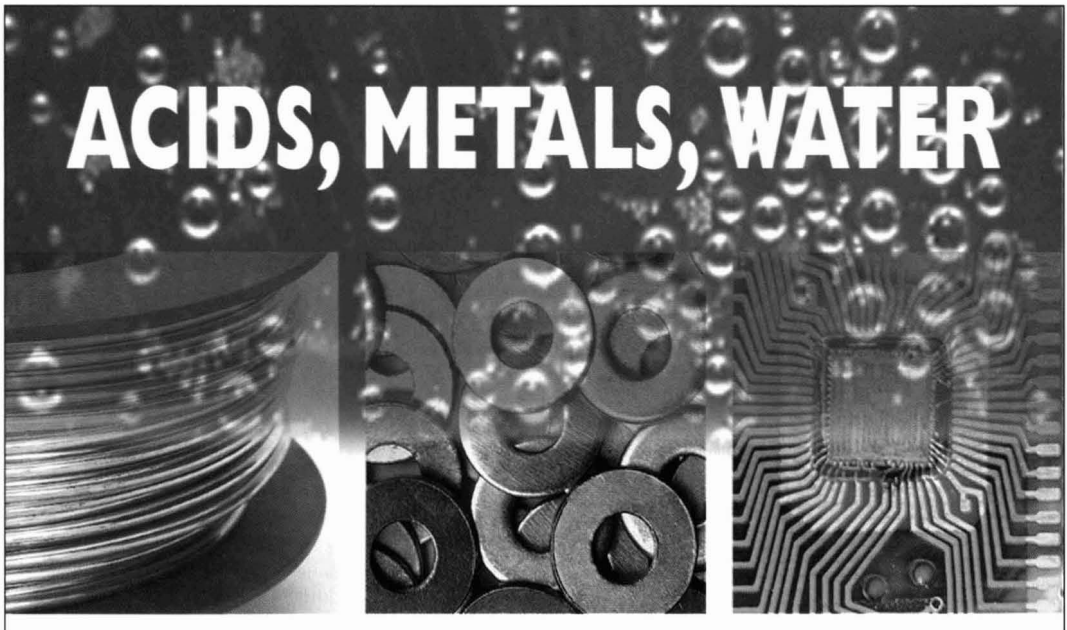
Thousands of sites in the United States contain groundwater contaminated with gasoline derivatives such as benzene, toluene, ethylbenzene and xylene. This group of constituents, collectively described as BTEX, are water-soluble aromatic compounds that can migrate with the groundwater and contaminate potable drinking water supplies. However, many sites are located in remote, rural areas where groundwater contamination poses no immediate threat to human health or the environment.

Studies show that BTEX compounds in the groundwater will degrade under aerobic conditions when oxygen is present in the system. BTEX-degrading bacteria will also consume oxygen during BTEX metabolism, which often results in the system becoming anaerobic. To ensure BTEX degradation continues even in remote areas, it is necessary to maintain an adequate oxygen supply to the groundwater. This is difficult at sites lacking electricity or accessibility at certain times of the year.

Site Characteristics

The U.S. Forest Service did a field study to evaluate the effectiveness of subsurface air infiltration and ventilation in controlling and removing BTEX from the soil and groundwater at the site of two leaking underground storage tanks (LUSTs). The contamination was discovered in 1991 during the removal of underground fuel tanks at two U.S Forest Service Guard stations in central Idaho.

The U.S. Forest Service guard station is located about 40 miles northeast of Cascade, Idaho, on the Cascade Ranger District of the Boise National Forest. The site, used primarily as a maintenance station for the national forest, is near the Warm Lake summit at about 6,000 feet elevation. The area geology is characterized by decomposing granite derived from the Idaho Batholith. Subsurface soils consisted primarily of medium to coarse sand with localized gravel and minor fine sand and silt. A shallow water table was present at 20 to



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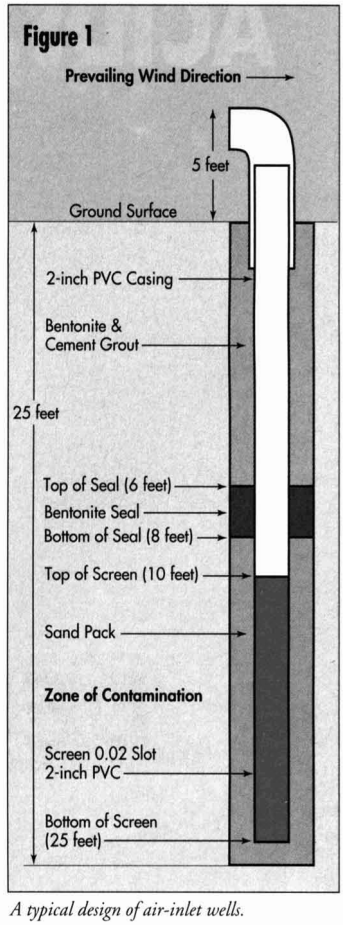
30 feet below the surface. A subsurface investigation involving soil sampling and the installation of groundwater monitoring wells was conducted to determine the extent of lateral and vertical contamination, as well as aquifer parameters. The data collected in the vadose zone indicated the presence of BTEX 5 to 30 feet below the ground surface and at site-specific cleanup levels.

System Design

In previous studies of the fate and transport of BTEX in sandy aquifers, biodegradation occurred rapidly when adequate oxygen is available. These studies also demonstrated that BTEX biodegradation is limited primarily by oxygen availability. When sufficient oxygen and nutrients are available, biodegradation is controlled only by the growth of naturally occuring BTEX-degrading microorganisms. If oxygen is introduced under natural conditions, this growth and the rate of biodegradation would be limited by nitrogen availability.



A typical design of air-inlet wells.

Because the forest service guard station is located in a remote area, is inaccessible five months of the year due to abundant snowfall and lacks electricity, the system was designed to evaluate the effectiveness of introducing oxygen to the subsurface under natural conditions without electrical pumps, sparging equipment or portable generators. The full-scale system design consisted of a series of air-inlet wells (the air treatment gallery), venting wells, observation wells and monitoring probes to evaluate the bioremediation/ venting performance and optimum well spacing and configuration. Each cell consisted of two venting or vapor recovery wells, positioned between four air-inlet wells. The distance between the venting wells and the adjacent air-inlet wells is about 20 feet. The rationale for the cell configuration was to eval-

uate the effect of different distances between the air-inlet and venting wells with regard to system efficiency (for bioremediation) and elimination of hydrocarbon vapors from the vadose zone soil.

The venting and air-inlet wells were constructed of 2-inch ID schedule 40 PVC casing (**See Figure 1**). The inlet wells extended from the surface to 10 feet below the water table. The portion of the wells that extended below the water table consisted of 0.10-inch slotted PVC well casing. The venting wells extended from the surface to just above the water table, with the bottom five feet consisting of 0.10-inch slotted PVC well casing. The bottom of each well screen was fitted with a solid cap. The venting and air-inlet wells were designed to aid lateral air and vapor flow through the vadose zone. A series of vapor monitoring probes were installed to just below and just above the water table to obtain depth-discrete samples.

Performance Monitoring

Measurements were made during the study to monitor the effect of bioremediation of the hydrocarbon-contaminated groundwater as well as the effects of subsurface ventilation on the vertical and horizontal distribution of hydrocarbon vapors. This allowed for semiquantitative analysis of the various hydrocarbon fractions that comprise gasoline. The system was monitored regularly for temperature, pH, carbon dioxide, dissolved oxygen (DO) and benzene. Air flow rates, photoionization detector (PID) readings and DO measurements were evaluated over time to determine the remediation progress. Water samples were collected from observation wells on a bimonthly basis to evaluate aquifer conditions.

Summary and Conclusions

Groundwater concentrations of BTEX were reduced to nondetectable levels during the initial five months of operation while vadose zone soil levels were reduced approximately 75 percent by a combination of natural attenuation, bioremediation and volatilization. The use of air treatment galleries at remote sites can be an efficient and cost-effective means to introduce a sufficient oxygen supply to shallow aquifers to allow the in-situ bioremediation of BTEX constituents. When combined with passive soil venting, the concentration of BTEX constituents in both vadose zone soils and groundwater can be reduced to below site-specific clean-up levels.

Air sparging and soil vapor extraction techniques would undoubtedly have been more effective and could have probably increased the rate of degradation to less than one month. Though pump and treat methods also would have ensured the stability of the contaminant plume, these techniques generally require constant maintenance and a power source not available at remote sites. In areas where there is no immediate threat to public health or the environment, a cost-effective approach is typically favored over remediation efficiency. The combined use of of air treatment galleries and soil venting, under the right conditions, promises a cost-effective solution. EP

Kent S. Murray, PhD, is an assistant professor of Geology and Environmental Science at the University of Michigan-Dearborn. Joseph and Sharon McNeal are principals of Consolidated Engineering Technology, an environmental services consulting firm in Boise, Idaho.

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A Successful Alliance

A public-private partnership reduced liability and provided extra benefits for a city wastewater system.

By John Grove, Jeff Blackwell and Monte Boynton

As environmental regulations become more complex and stringent, the efficient operation of wastewater facilities becomes more difficult. To match the pace of changing regulations, many municipalities have turned to public-private partnerships for contract operation, maintenance and management (OM&M) of these facilities.

Kenner, La., originally looked to a partnership of the city's wastewater facilities to reduce potential environmental liabilities. However, after more than a year of service, the city has discovered that the benefits of an efficient public-private partnership extend to many aspects of government and far beyond the realm of wastewater treatment. Kenner has not only improved services for residents and provided new benefits for employees, but ensured compliance with regulations.

Kenner, La., located on the outskirts of New Orleans, experienced periodic overflows due to wet weather events. Wastewater supervisors determined that a plant expansion and better maintenance of the collection system was required to fix the problems. City officials decided a private firm might be best to provide technical expertise for the project.

The Kenner city council issued two requests for proposals, one for the wastewater plants and one for the collection system.

The council voted unanimously to award a contract for both the plants and the collection system to Professional Services Group Inc. (PSG). This decision was partly based on the recommendation of a third-party municipal management consultant. A thorough evaluation ranked PSG's proposal the best among those submitted for the contract in terms of operator qualifications, technical approach and contract price.

Photo courtesy of the city of Kenner, La.

Kenner, La., contracted out the operation, maintenance and management of its wastewater treatment system to a private firm.

The city began its partnership for the OM&M of its 15 million gallons per day (MGD) municipal wastewater system on July 1, 1995. It included a 263-mile collection system, 3,000 manholes, 76 lift stations and 5-MGD, 4.75-MGD and 5.25-MGD secondary wastewater treatment facilities. The wastewater system serves 75,000 Kenner residents, New Orleans International Airport and a portion of Jefferson Parish.

Photo courtesy of the city of Kenner, La.

In the past year, the city and the contract operator issued more than 4,500 work orders, which is three times the amount issued the previous year.

Employee Benefits

PSG assigned an experienced project manager to Kenner and hired all 75 of the city's wastewater employees at comparable wages and benefits. This allayed employee fears about pay cuts and layoffs.

After the private firm began operating the wastewater plants, the former city employees found that the departmental changes were not as radical as expected. The firm provided a work atmosphere that encouraged individual contribution, which made a significant improvement in morale. Workers were also given opportunities to develop individual skills and experience through continuing education programs.

One of the company's first priorities was implementing safety training sessions for the former city employees. In the last year, wastewater plant employees received over 2,000 manhours of training. The private firm also offers classes in management, mechanics and aid for employees getting licenses.

Technological Improvements

In the first year of operation, the private partner focused on using new technologies to improve operations. For example, the company is installing a specialized computer program to organize plant and collection system maintenance.

Under the current system, when complaints and service requests are received, they are written down and an employee is sent to make the necessary repairs. The new software, called Hansen, will collect data on every work order and service request. It will use this information to schedule preventive maintenance. Areas in the collection system that need frequent servicing will receive periodic maintenance, ultimately saving time and expenses by correcting problems before they happen.

The same software will also be used to track maintenance in each of the three wastewater plants, and will compile costs of labor, equipment and parts. Eventually, the Hansen software will control all processes, maintenance and accounting.

To reduce energy costs, variable speed drive units and motors have been installed on all effluent stations and some aeration stations in response to a recent energy study. In addition, treated wastewater is now recycled and used in the wastewater chlorinators, resulting in a significant reduction in the department's water bill.

Compliance Issues

One of the biggest tasks in the first year of the partnership in Kenner was to assist in reduction of inflow and infiltration into the wastewater collection system, which can cause combined sewer overflows. As part of the contract, the private firm has assumed responsibility for any potential liabilities from permit violations.

The company initiated a comprehensive program for better maintenance of the collection system, which included replacing pumps at the city's lift stations and instituting studies on flow records and rainfall.

Kenner's wastewater compliance plan committee, composed of city representatives, several consulting firms and a PSG representative, were responsible for a 3 MGD expansion of the 5.25 MGD plant, which came on line last November. This

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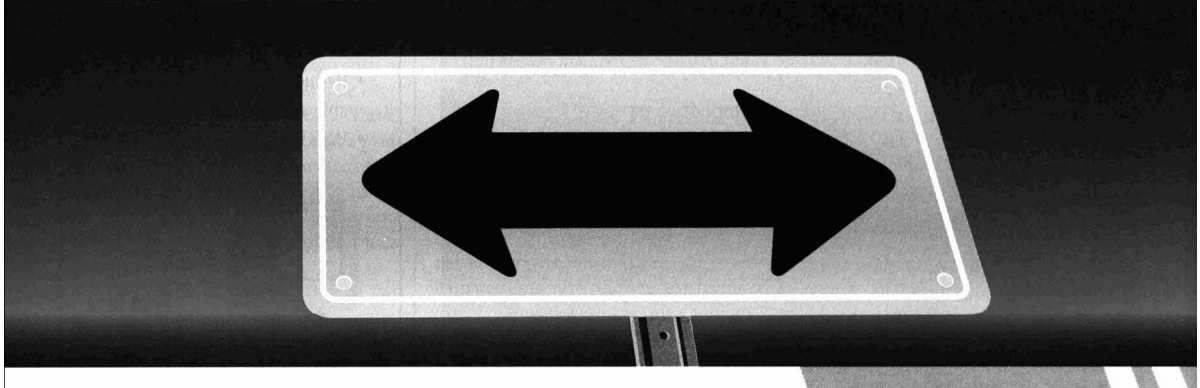

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expansion of the plant to 8.25 MGD will also help the city to better process excessive flows during heavy rainfall.

PSG also installed telemetry systems at several of the city's lift stations. In case of an emergency at an outlying location, the system will call operators and, with a voice synthesizer, alert them of the problem. There are plans to phase in the installation of this system at the remaining lift stations.

One of the biggest tasks in the first year of the partnership in Kenner has been to assist in reduction of inflow and infiltration into the wastewater collection system, which can cause combined sewer overflows.

General Maintenance

There have also been general improvements to the Kenner wastewater facilities. The city and PSG issued more than 4,500 work orders in the first year of the partnership, which is more than three times the amount issued the previous year. Projects included: cleaning and rehabilitating grit ponds; painting buildings and trucks; replacing roofs on lift stations and rehabilitating drying beds. The city has saved significantly by having PSG do the labor rather than hiring an independent contractor.

However, wastewater system OM&M is an ongoing process. There are a number of projects planned for the next 12 months. The city is considering a new diffused aeration system for one of the plants, which PSG may assist with or completely install. The company is also continuing to evaluate the need for pump station upgrades and rehabilitation.

Currently, Kenner's biosolids meet class B requirements, which means they must be disposed of in a landfill. However, PSG plans to improve the quality of the biosolids to class A level for beneficial reuse. The biosolids then can be marketed and sold or given away for use as fertilizer, resulting in further cost savings for the city.

The public-private partnership approach to treatment system OM&M has benefited the city of Kenner by helping to increase operational efficiencies and improve the overall quality of its wastewater treatment services for its residents. Through contract OM&M, the city has also reduced OM&M costs while maintaining compliance with environmental standards. EP

John Grove is director of wastewater treatment for the city of Kenner, La., Jeff Blackwell is area vice president of client services for PSG and Monte Boynton is operations specialist for the PSG Kenner project.

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A V System Inc. 4657 Platt Rd. Ann Arbor, MI 48108 313-973-3000 FAX: 313-677-4480 ***Circle 1 on card.***	NPDES	▲				▲	▲	▲	▲		▲	▲			▲	Tracks National Pollutant Discharge Elimination System (NPDES) permits and maintains Discharge Monitoring Reports (DMR) for Clean Water Act compliance.
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	Lab TRAQ					▲	▲	▲	▲	▲	▲				▲	Laboratory information management system.
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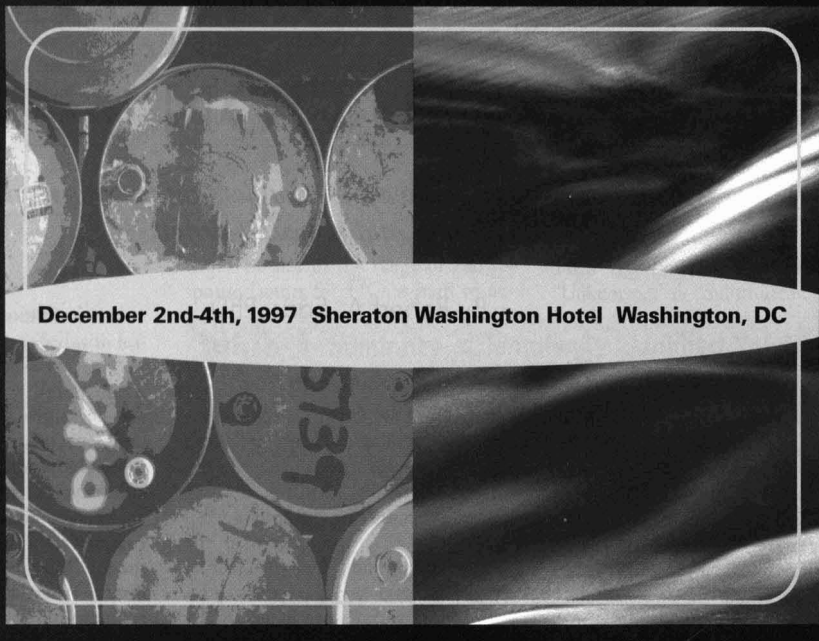

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PROCEED WITH CAUTION

TIC information is not always a reliable basis for investigatory conclusions and remedial design.

By Robert A. Saar, PhD

Site investigators may need to interpret organic compound data for chemicals not on the laboratory's standard (target) calibration list. These organic tentatively identified compound (TIC) data have the appearance of data for target compounds, but unlike target compounds, TICs are not surely identified or quantified. Although there are no specific regulatory drivers, state and federal regulators sometimes require TIC data in reports for soil and water contamination investigations. Underlying this request is the presumption that the data might be used in decision-making. But TIC data alone should not form the basis for conclusions about site conditions or for remedial design.

Organic TIC data are generally most usable when one or a few non-target compounds are prominent at a site. That is not the case at most industrial facilities, where myriad TICs (solvents, petroleum compounds and their environmental breakdown products) are present. The problems of using such data fall into three categories: uncertainty of TIC identification, uncertainty of TIC quantitation and uncertainty of the toxicological impact of TICs.

Uncertainty of TIC Identification

Gas chromatography/mass spectroscopy (GC/MS) scans for organic compounds involve formal identification, calibration and quantitation for 20 to 40 target volatile organic compounds (VOCs) and 60 to 80 target semivolatile organic compounds. The GC/MS instrument uses both the retention time in the gas chromatography column and the spectral pattern in the mass spectrometer to identify the target compounds. Identities are confirmed by comparing the spectra from the sample with the spectra of the known compounds used to calibrate the instrument.

In contrast, TICs are identified by matching the compound's mass spectral pattern with a library of known spectra that are programmed into the instrument. No calibration is performed using a known sample of the suspected TIC. GC/MS computer libraries have 40,000 to 80,000 spectra for possible matching with TICs, but these spectra represent only a small fraction of the possible organic compounds in environmental samples. The attempt to identify a TIC combines both the GC/MS computer matching algorithm and the experience of the GC/MS analyst. The computer designates the quality of the match on a scale of 0 to 100 percent "purity" or "probability of match." A 100-percent match means the locations and sizes of the mass spectral peaks for the compound in the sample exactly match those for the compound in the instrument's computer library.

Organic TIC data are generally most usable when one or a few non-target compounds are prominent at a site.

However, the ability to match the compounds in the sample with those in the GC/MS computer library is often limited. Many compounds in the environment do not have library spectra, and even for compounds present in the spectral library, some samples have so many other compounds (an interfering matrix) that the spectrum is distorted, thereby confounding the match. Often, the best match is considerably less than 50 percent.

Industrial sites have a wide array of compounds in soil and groundwater. Petroleum facilities have many chain and ring hydrocarbons, each having many variations of molecular size and structure. In addition, environmental oxidation can create many degradation products, including aldehydes, ketones, carboxylic acids, esters and phenols. Some of these compounds occur naturally in subsurface environments where there is biological activity. For the site recently investigated, a petroleum facility in the eastern United States, **Table 1** provides an overview of the major groups of TICs and the percentage of TICs that are listed as "Unknown," "Unknown...," "Substituted..." and specific, identifiable compounds.

Can the identification of TICs be improved? In most cases, not appreciably without major effort. The GC portion of the GC/MS instrument cannot definitively separate the multitude of components, so the resulting mass spectrum

potentially includes contributions from several compounds, making it extremely difficult to interpret. Even with a simple mass spectrum, the quality of the match may be low, indicating the compound is not in the computer library. Despite computer and analyst efforts, "unknown" or "unknown alkane," for example, is often the best identification that is practical in the short time available at a commercial laboratory. The true identification of many TICs would typically be a research exercise, which is not the core business of most commercial laboratories.

Uncertainty of TIC Quantitation

Even if a TIC can be identified with reasonable surety, the reported TIC concentration is crudely approximate. Laboratories do not normally give any indication of the large errors potentially associated with these numbers. The explanation for the uncertainty of TIC concentration starts with the calibration for target compounds. The GC/MS system responds differently to each compound. The instrument's sensitivity to a compound is its "response factor." The U.S. Environmental Protection Agency protocols specify running five calibration standards for each target compound. The instrument's peak heights (the response) are graphed against the concentrations for the standards. If the points of the graph were to fall exactly on a straight line, the relative response factors (RRFs) for the five standards would be identical, and the relative standard deviation (RSD) for the RRFs would be zero.

In real analysis, the RSD ranges from a few percent to several tens of percent. For data from this petroleum site, 2,4-dinitrophenol and n-butyl alcohol have RSD values above 30 percent. According to EPA protocols, there are no RSD acceptance criteria for these and other relatively water-soluble organic compounds, and the maximum allowable RSD for other less soluble organic compounds is 20.5 percent. Therefore, even for target compounds, quantitation is uncertain to some degree based on the data scatter surrounding the calibration line.

Response factors for target compounds vary from calibration to calibration within a laboratory and potentially even more between laboratories. Using this site's data, interlaboratory results for target compounds showed that some RRFs in the volatiles fraction were different by more than a factor of six, an expected and consistent variation that is consistent with common laboratory practice.

The problem of quantitation is even greater for TICs. For target compounds, the RRFs are known and each target compound has a calibration curve. TICs have no calibration curves, so the RRFs for the TICs are assigned the values for the closest internal standard that is free of interference The size of the range of real response factors for TICs is hard to determine, but it is undoubtedly larger than the range of RRFs for target compounds. For calibrations done for this project, the RRFs for various target compounds range from approximately 0.01 to 4 for VOCs and from 0.15 to 2.5 for semivolatile organic compounds within the same laboratory. The large uncertainty of RRFs for TICs results in an estimate of concentration that can be off by an order of (10 times) magnitude or more. Any tabulation, mapping, calculations, designs or toxicological assessment using TIC data needs to account for this order-of-magnitude uncertainty.

Uncertainty of the Toxicological Impact of TICs

To assess a compound's toxicological impact, its identity must be known. Exposure calculations will be uncertain to the degree that the compound quantitation is uncertain Even TICs with a good spectral match may not be the exact compound that is in the sample. Alternatively, the laboratory report may list compound groups such as "substituted benzene" or "unknown alkane."As shown in **Table 1**, 92 percent of the soil TICs and 87 percent of the groundwater TICs are classified at "Unknown," "Unknown..." or "Substituted..."

Table 1 Summary of Tentatively Identified Volatile and Semivolatile Organic Compound Groupings in Multiple Soil and Groundwater Samples, Petroleum Products Facility, Eastern United States.

Grouping	Soil		Groundwater	
	Number	Percent	Number	Percent
Total number of TICs	5124	100	1862	100
Top 10 Groups of TICs*	4694	92	1465	79
TICs listed as "Unknown" or "Unknown..."	3375	66	1173	63
TICs listed as "Substituted..."	1355	26	444	24
TICs listed as specific compounds	25	0.5	115	6

* The following top 10 groups of TICs are based on frequency of occurrence.

Soil Groups: Unknown; Unknown alkane; Substituted naphthalene; Substituted alkane; Unknown hydrocarbon; Substituted benzene; Substituted acid ester; Aromatic hydrocarbon; Oxygenated hydrocarbon; Substituted phenanthrene.

Groundwater Groups: Unknown; Substituted benzene; Substituted acid ester; Unknown alkane; Substituted naphthalene; Substituted ester; Substituted alkane; Unknown acid; Substituted indene; Aromatic hydrocarbon.

Although these family designations may be accurate, there is no way to do a toxicological evaluation when the toxicological properties of even closely related compounds can be widely different. The current scientific research literature is full of examples. DDT and methoxychlor have only slightly different structures—a chloride (-Cl) in the large molecular structure of DDT is replaced by a methoxy group (-OCH_3)—but methoxychlor is 20 to 60 times less toxic. The geometric variants, or isomers, of hexachlorocyclohexane range from biologically inactive to convulsant poison. Wide variations in toxicity also

occur within the families of polychlorinated biphenyls (PCBs) and dioxins. While many petroleum compounds have relatively low toxicities, the uncertainty of identification and toxicology remains an important issue.

Toxicological evaluations are more credible when specific compounds are identified. **Table 1** shows that only 0.5 percent of the soil TICs are specific compounds; the remainder are "Unknown," "Unknown..." or the member of a family of compounds ("Substituted..."). For groundwater, 6 percent of the TICs are listed as specific compounds. Even when there is high confidence in the TIC's identity and the TIC is a specific compound, it is likely that little or no toxicological information is available. For this site, the EPA has toxicity values for only two soil TICs (naphthalene and benzo[b]anthracene) and two groundwater TICs (atrazine and benzoic acid).

When a specific TIC is identified with surety and toxicological information is available, the concentration of the compound needs to be known so exposure calculations can be performed. The TIC "concentration" listed in the laboratory reports can easily be in error by an order of magnitude or more. This large uncertainty in concentration limits the usefulness of exposure calculations. EP

Even when there is high confidence in the TIC's identity and the TIC is a specific compound, it is likely that little or no toxicological information is available.

Summary

- There are large uncertainties in identification and quantitation of TICs.
- For remediation planning and toxicological assessment, it is not defensible to treat TICs like target compounds.
- TIC data are qualitative at best.
- A review of data from this petroleum site shows that most TICs are hydrocarbons and partially degraded hydrocarbons.
- The total petroleum hydrocarbon (TPH) test largely accounts for TICs, making it unneccessary to obtain or evaluate TIC data as the site moves toward remediation.

Robert A. Saar, PhD, is a senior geochemist in the Minneapolis, Minn. office of Geraghty & Miller Inc., a national environmental and infrastructure consulting firm.

Combustion Technology

Thermal treatment proves effective in reducing low-volume high concentration No_x chemical process off gas.

By Hal Shelton

Controlling oxides of nitrogen (NO_x), one of the major pollutant gases, can present a significant challenge to combustion gas technologies. However, low NO_x burners, using staged combustion (either air or fuel), have been successfully applied minimizing NO_x formation in boilers, process heaters and other low-temperature chemical processes. The burner design principals inhibit by keeping the adiabatic flame temperature, which is the temperature of completed combustion if no heat is lost, lower than required to breakdown atmospheric nitrogen (N_2) or delaying combustion reactions until flame temperatures drop within a firebox, boiler or other equipment that absorbs heat.

Combustion technology has also been used to reduce NO_x formed via chemical processes or generated when burning nitrogen containing chemical compounds. These designs normally require staged burning and incorporate either energy recovery, flue gas (process exhaust gases) recirculation, or using a second, low temperature inert gas stream (as diluent) between combustion stages. Interstage cooling and temperature control are necessary to maintain low NO_x emissions. When the requirement for 90-percent NO_x removal was necessary for a low-volume, high NO_x concentration (approximately 13-percent nitric oxide) process off gas, thermal treatment was selected as the preferred technique. This approach is diametrically opposed to what is conceived as normal combustion technology, where products of combustion will produce low to moderate NO_x emissions in hot gases.

As NO_x emission concentrations increase (primarily from combustion nitrogen bound chemical compounds), thermal treatment becomes viable. NO_x removal technology becomes preferrable when energy recovery is practical because the process is simple and final, with no residual waste requiring disposal.

Process Challenge

A federal government facility located in northern Alabama operated a research and development plant producing chemical grade phosphoric acid. The plant was shut down and left residual elemental phosphorus that, if exposed to air, is subject to spontaneous ignition. Handling and transportation for off-site disposal problems dictated that the solution remain within the facility. This waste elemental phosphorus, when mixed with nitric acid, produces a fertilizer precursor (or feed stock) that can be sold as a usable byproduct. The generic reaction kinetics are:

$HNO_3 + P + H_2O$ (excess) = $H_3PO_4 + NO_x + H_2O$ (excess)

(nitric acid) + (phosphorus) + (water) = (phosphoric acid) + (oxides of nitrogen) + (water)

The water acts as a reaction moderator. As shown, off gases contain large volumes of NO_x (primarily nitric oxide) and water vapor. Air leakage converts some nitric oxide (NO) to nitrogen dioxide (NO_2).

Bench testing confirmed the waste gas contained up to 13-percent NO_x, which is 90-percent NO.

The process developed has a two- to three-hour batch cycle time with peak emission reaction products evolving during the first hour. Emissions are initially zero, peak at 130,000 parts per million (ppm) NO_x and then decay exponentially during the remaining cycle. Five to eight batches are processed in a 24-hour period. This disposal process has an expected 3-year life until all phosphorus is used.

Equipment Selection and Design

The project manager conducted a technology search. Wet scrubbing, non-catalytic and direct catalytic reduction, and thermal treatment were evaluated to determine the best technology that would meet a required 90-percent NO_x removal rate.

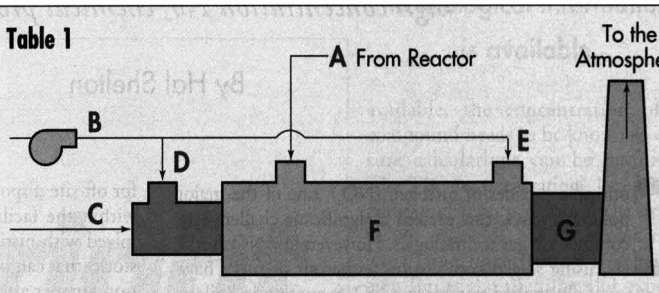
Low exhaust volume (245 standard cubic feet per minute (scfm)) and high NO_x concentrations complicated the technology selection. Catalytic reduction, an accepted technology for large industrial and utility boilers, was costly. Vendors were also reluctant to provide NO_x reduction guarantees for the unique process conditions of low

volume, high concentration NO_x.

Exhaust gas volumes (245 scfm) are lower than standard scrubber designs. Chemical treatment is also required to convert NO to NO_2, which is water soluble. Effluent discharge, which is corrosive, also requires neutralization. Fully automating the process was not cost-effective. Necessary controls turned the facility into a small chemical plant.

Selective non-catalytic reduction (the reduced nitrogen/NO_x reaction takes place entirely in the exhaust gases without the presence of a catalyst) using ammonia was not viable. The NO_x emission range and temperature limits for effective NO_x reduction is narrow and requires a precise control scheme. Missing the temperature window and proper ammonia ratio would produce more NO_x or result in excessive ammonia slippage (the excess will go unreacted to the atmosphere and is a pollutant). Complex monitoring is necessary to meet the varying NO_x limits occurring during a batch cycle.

Table 1



Component	Waste (A)	Comb. Air (B)	Aux. Fuel (C)	Prm. Air (D)	Sec. Air (E)	Reducer (F)	Exhaust (G)
Flow Rate (#/Hr)	792	851	76	595	256	1,463	1,717
Flow Rate (SCFM*)	245	186	11	130	56	379	561
Temp (°F)	230	60	60	60	60	2,200	1,700
Composition (#/Hr)							
N_2 (Nitrogen)	71	655	—	458	197	592	789
O_2 (Oxygen)	21	196	—	137	59	—	28
H_2O (Water)	550	—	—	—	—	655	682
NO (Nitric Oxide)	150	—	—	—	—	15 (max)	15 (max)
CO (Carbon Monoxide)	—	—	—	—	—	13	—
H_2 (Hydrogen)	—	—	—	—	—	3	—
CO_2 (Carbon Dioxide)	—	—	—	—	—	185	205
C_3H_8 (Propane)	—	—	76	—	—	—	—

*Standard Cubic Feet Per Minute

Propane gas auxiliary fuel provides heat for both combustion and as a NO_x reducing agent (a reaction that removes the oxygen from the NO_x molecules). **Table 1** represents the process flow conditions.

The thermal reducer is a two-stage design with the first stage operating at a nominal 70-percent theoretical air. This theoretical air ratio was chosen for flame stability and produced a reducing temperature between 2200° F and 2400° F, which is necessary for stripping the oxygen from the NO_x compounds. Process vapor supplies 20 percent of the first stage oxygen requirement via NO_x and process air in leakage. Burner combustion air contributed the remaining 50-percent theoretical air. The burner flame is stabilized by a continuous pilot. NO_x vapor is introduced into the burner flame via gas bustle with sufficient gas penetration to promote intimate mixing. Reaction kinetics, which are the various chemical reactions, are:

$C_3H_8 + O_2^* + NO_x = H_2O + CO_2 + CO + H_2 + N_2$

(propane) + (oxygen) + (oxides of nitrogen) = (water) + (carbon dioxide) + (carbon monoxide) + (hydrogen) + (nitrogen) (*Oxygen supplied by primary combustion air and air leakage into the process vapor).

$CO + NO = CO + CO_2 + N_2$

(carbon monoxide) + (nitric oxide) = (carbon monoxide) + (carbon dioxide) + (nitrogen)

$H_2 + NO = H_2O + H_2 + N_2$

(hydrogen) + (nitric oxide) = (water) + (hydrogen) + (nitrogen)

A 2.0-second reducing (less than required oxygen) residence time allows the reaction to approach completion. Quench (cooling air) /oxidizing secondary air is added at the first stage outlet to oxidize partial combustion products from the reduction stage. This secondary air must mix rapidly and completely to fix (prevent the reaction from continuing) the reaction and prevent thermal NO_x formation. Quenched gases at 1700°F completely eliminate the partially combusted products of combustion and provide some excess air.

All combustion materials in contact with the waste vapor were fabricated from 316 L stainless steel. A drain was included at the ductwork low point for disposal of any liquid condensate. Equipment was shipped prepackaged to minimize installation and startup costs.

Operation

Based upon an initial equipment cost of $50,000, no chemical consumption and minimal personnel requirements, thermal reduction was the selected technology.

Other reasons included:

- Simplicity of equipment that does not require an operator to be present at all times;
- Solution was final—no residual waste to neutralize or further treat;
- Tolerance to process changes; and
- Utility requirements were propane gas auxiliary fuel.

Equipment was designed to comply to Industrial Risk Insurance (IRI) standards.

Primary air and propane auxiliary fuel is mechanically linked with a 50-percent theoretical air/propane ratio. Remaining secondary air varies depending on the first stage heat load. The exhaust temperature is measured and controlled by varying the primary air/propane ratio.

The equipment is warmed up using outside fresh air. Once up to the proper temperature, the waste vapor valve is opened and the fresh air valve is closed, which provides a smooth transfer of waste vapor without a temperature bump (sudden change in temperature) caused by high moisture waste vapor.

When operators commissioned (checked out and started up) the equipment, the first stage combustion was more intense than expected. The measured air/fuel split was inconsistent with the engineering data. Upon investigation, the operators determined that the process gas had more oxygen than pilot test data indicated. This was primarily in the form of excessive NO_2 (less NO). Rather than further reducing the burner air/fuel ratio and risk burner instability, a propane bleed stream was recommended to be introduced into the process gas plenum (where the gas distributes itself in the burner). After making these minor adjustments, the unit was started and inlet/outlet concentrations measured. Throughout the operating conditions and emissions variations from the batch process, the thermal reducer consistently met the 90-percent NO_x reduction requirements.

Summary

Process gases with low NO_x concentrations can be effectively removed using wet scrubbing or low-temperature catalytic reduction. As NO_x emission concentrations increase (primarily from combustion nitrogen bound chemical compounds), thermal treatment becomes viable. NO_x removal technology becomes preferrable when energy recovery is practical because the process is simple and final, with no residual waste requiring disposal. The final design of any industrial system should incorporate heat recovery such as steam generation, hot oil heating or even fume preheating.

Hal Shelton, BS, chemistry, and MS, materials engineering, is senior business leader at SE Technologies in Bridgeville, Pa.

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Environmental Liability Changes Benefit Industry

Changes in lender and fidicuary environmental liability should benefit both businesses that borrow and financial institutions.

NEW PROTECTIONS PROVIDED BY the federal government for lenders could make loans easier for industry to obtain. Similar protections for fiduciaries, persons administering the assets of trusts on behalf of others, could ease the creation of trusts and other fiduciary vehicles, especially benefiting closely held and family-owned businesses. Because the new protections can shield financial institutions from many environmental liabilities, the institutions should have more flexibility to enter loan or fiduciary arrangements on industrial properties. Industries should find that fewer loan applications are rejected for environmental reasons and it should become easier to deed industrial properties to trustees.

For industry, the lender rules mean that borrowing may become easier because lenders now have a relatively clear test to avoid liability.

The U.S. Congress provided these protections in the Asset Conservation, Lender Liability and Deposit Insurance Protection Act of 1996, which was part of the September 1996 omnibus budget law. The act provides safe harbors for lenders and fiduciaries with regard to facilities and vessels (collectively referred to as "sites") under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as Superfund, and to underground storage tanks (USTs) under the Resource Conservation and Recovery Act and the Solid Waste Disposal Act.

These safe harbors provide more certainty for lenders and fiduciaries to manage environmentally sensitive properties in their loan or trust portfolios. As a result, industries should find their future relations with lenders and trust officials to be more straightforward and simplified.

James L. Koewler, Jr. *practices environmental and occupational safety & health law in Cleveland, Ohio.*

Lender Protections

For lenders, the act legislatively adopts a 1992 rule of the U.S. Environmental Protection Agency that outlined the actions lenders could take with respect to contaminated sites without becoming liable as "owners" under CERCLA. At the same time, the act precluded any similar attack on the EPA's authority to promulgate lender liability rules for USTs by specifically authorizing the 1995 rules.

The CERCLA and UST requirements for lenders are very similar. Lenders must avoid "participating in the management of" CERCLA sites and USTs. For CERCLA sites, the lender must avoid exercising decision-making control to such a degree that it has "undertaken responsibility for the borrower's hazardous substance handling or disposal." For USTs, the lender must not have "undertaken responsibility for all or substantially all of the management of" the UST or UST system.

In both the CERCLA and the UST context, the lender must not "exercise control at a level comparable to that of a manager" of the borrower's business. The lender may exercise control over financial or administrative matters for the business, even if those matters involve the CERCLA site or USTs. In addition, a lender will not be held liable if it has the mere "capacity to influence or the unexercised right to control."

These tests apply to any actions taken during the life of the loan, including loan policing and workout activities, which are negotiated restructurings of loans after a repayment problem arises or is predicted.

The rules also provide lenders protection to foreclose on environmentally tainted sites or on USTs. The lender must demonstrate its intent not to remain the owner by offering the property for sale, "at the earliest [practical], commercially reasonable time, on commercially reasonable terms, taking into account market conditions and legal and regulatory requirements."

If the lender receives an unconditional cash purchase offer for a price high enough to recoup all costs, outstanding debt and interest, the lender

must accept. If it rejects, fails to act upon, or outbids such an offer, the lender will be considered the "owner" for CERCLA and UST liability purposes.

For USTs, unless there is an actual "operator" such as a tenant, the lender must also temporarily close the tanks, maintain corrosion protection and report any suspected releases. If the tanks remain temporarily closed for more than 12 months and do not meet the current requirements for new tanks and tank upgrades (other than spill or overfill requirements), the lender must investigate for leaks.

Despite this new protection, industry should not expect lenders' environmental scrutiny to cease. While the act reduces the risk to lenders of their own liability, it does not reduce the liability of borrowers. Consequently, lenders should continue to scrutinize the environmental conditions of prospective borrowers to weed out those who may not be able to repay the loan.

Fiduciary Protections

Similarly, fiduciaries should not reduce their environmental scrutiny either. The Act identifies the steps necessary for fiduciaries to limit their environmental liabilities to the assets held in a fiduciary capacity and avoid "individual" liability. However, mere liability avoidance is not the only goal. Fiduciaries do not want to own environmentally tainted property that is unmarketable and could even require maintenance to avoid liability.

For fiduciaries, the Act itself, rather than an EPA rule, outlines the safe harbor. The act provides that the liability of fiduciaries for Superfund sites and USTs is limited to the assets held in the fiduciary capacity. Using trusts as an example, the trust assets are available to satisfy CERCLA and UST liabilities, but the trustee's other assets are not available. A fiduciary can lose this protection if it acts negligently, adds to the contamination, or increases the likelihood that the contamination will migrate. The protection is also unavailable when the fiduciary relationship is created merely for the purpose of minimizing environmental liabilities.

Impact on Industry

For industry, the lender rules mean that borrowing may become easier because lenders now have a relatively clear test to avoid liability.

Lenders may also assert themselves somewhat more aggressively in non-environmental matters of the borrower's business. Because of the protection for loan policing, workout activities, and even foreclosure, lenders will no longer ignore problem loans because of potential environmental issues. The new protection for fiduciaries will allow industries to place more assets into trusts and other fiduciary arrangements. This will especially benefit family-owned businesses in estate planning. Most of all, by reducing environmental risks to financial institutions, the new law and rules should make loans more plentiful and financial plans easier. EP

The author gratefully acknowledges the editorial contributions of William E. Coughlin of Calfee, Halter & Griswold, LLP, in Cleveland Ohio.

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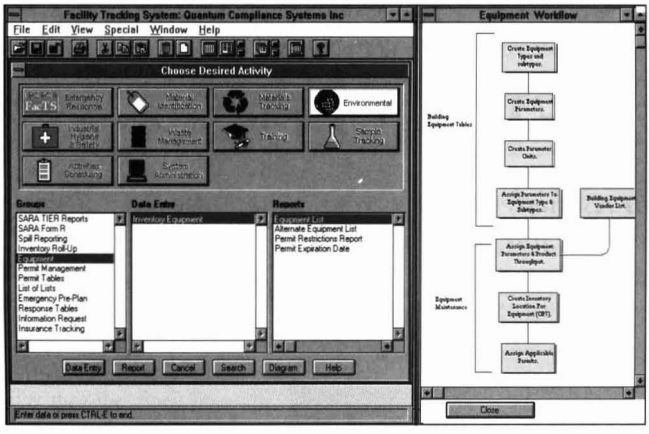

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Cost-Cutting Alternatives

Water treatment plant residuals can be used as a supplemental reagent for wet-limestone flue gas desulfurization reagent.

By Brad Buecker

Water treatment plant waste solids (residuals) have been used before as a supplemental reagent for wet-limestone flue gas desulfurization (FGD). Two recent tests of this material provide a fresh update on both the problems and practicality of this application. Reuse of water-treatment plant residuals (WTPR) offers treatment plant operators an alternative mechanism of sludge disposal and may offer electric utilities a reagent that enhances the flue gas desulfurization process. Today, where zero or reduced plant discharge has become very important at many facilities, conservation techniques such as this may have substantial merit.

Basic Chemistry

Figure 1 shows a simplified, but common, arrangement of a wet-limestone scrubbing tower. The essential chemical reaction is: calcium carbonate + sulfur dioxide + water = calcium sulfite hemihydrate + carbon dioxide ($CaCO_3 + SO_2 + {}^1/_2H_2O = CaSO_3 \cdot {}^1/_2H_2O + CO_2$).

At many facilities air is injected into the slurry to convert calcium sulfite to calcium sulfate: calcium sulfite hemihydrate + oxygen + water = calcium sulfate dihydrate ($CaSO_3 \cdot {}^1/_2H_2O + {}^1/_2O_2 + 1{}^1/_2H_2O = CaSO_4 \cdot 2H_2O$).

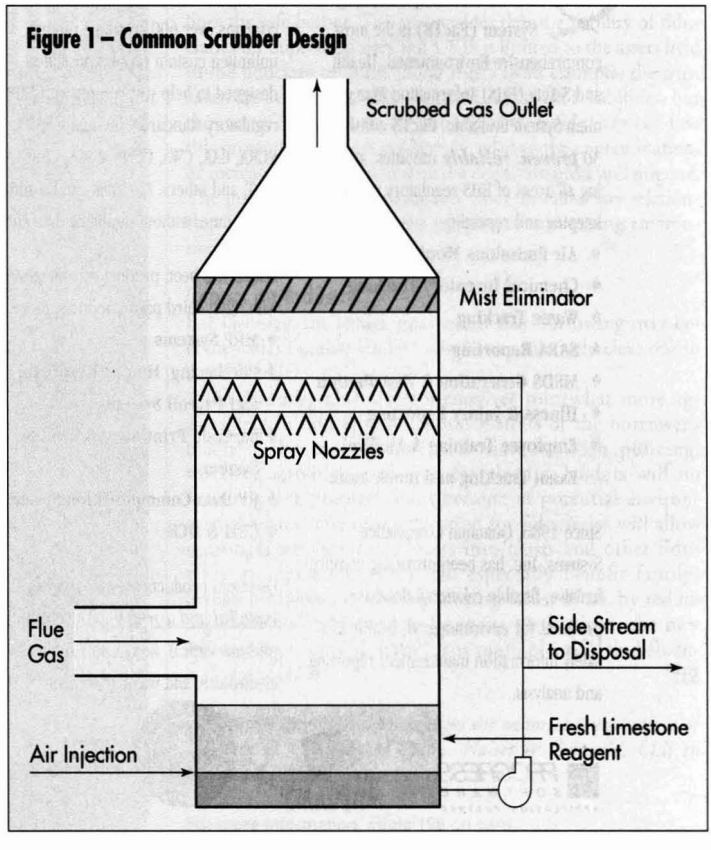
$CaSO_4 \cdot 2H_2O$ (gypsum) can be dried into a cake-like product by vacuum or pressure filters and subsequently disposed. If the gypsum content is approximately 93 percent or higher, the product may be suitable for manufacturing wallboard.

Factors Important For Scrubber Efficiency

Scrubber efficiency is greatly dependent on the properties of the reagent, as outlined below:

- Increased calcium carbonate content of the stone usually increases reactivity. Some systems operate poorly with stones that contain less than 95 percent $CaCO_3$. Even though magnesium can enhance the transfer of SO_2 into solution, dolomitic stones (limestones containing significant amounts of magnesium carbonate bonded with calcium carbonate)

Figure 1 – Common Scrubber Design



are rather unreactive in FGD systems.

• Limestone grind size is hugely important. In many FGD systems, the minimum grind size is set at 80 percent particle passage through a 325-mesh screen. Small grind size exposes more surface area, which allows the particles to dissolve and react before being removed by the waste disposal system.

• Chemical additives such as organic acids and soluble magnesium compounds can enhance the reactions. Organic acids aid the dissolution of limestone, while soluble magnesium provides additional alkalinity for pulling SO_2 into solution, where it can then react with calcium.

WTPR residuals have many of these properties. In particular, particle size is typically smaller than the finest limestone grind, and the solids usually contain magnesium hydroxide, which increases reactivity. The following two examples illustrate the potential benefits and problems of using WTPR residuals.

Test #1 - Reuse of Dried and Landfilled WTPR in a Liquid Byproduct FGD System

Test #1 was performed at a utility that burns coal containing less than 1 percent sulfur. The FGD system serves as a polisher to further clean the flue gas. The scrubber removes fly ash from the flue gas, which adds alkalinity to the system. The waste solids exit the system as a slurry and are collected in a pond, making waste disposal issues less critical than at other facilities.

The program consisted of nine tests, three with water treatment plant residuals, three with the limestone normally used at the plant, and three with a blend of residuals and limestone.

The WTPR were taken from a local treatment facility. These solids had been previously landfilled, and thus had to be excavated and trucked to the plant. **Table 1** shows a comparison between the chemical makeup of the residuals and the limestone.

Reagent for the FGD system is prepared in a wet-grinding ball mill. Both the limestone and residuals were passed through the mill during the tests. A sieve analysis revealed that 91 percent of the residuals particles but only 64 percent of the limestone particles passed through a 325-mesh screen.

Results

The full-scale tests revealed that the water treatment plant residuals were more reactive than the limestone, even though the chemical compositions were similar. The data, when plotted, showed that SO_2 removal versus unreacted product remaining in solution was greater (by a range of 4 percent to 11 percent) for the residuals than for the limestone. This indicates two advantages:

• Higher SO_2 removal could be obtained with the residuals.

• At the same SO_2 removal rates, less residuals would be needed than limestone.

One major difficulty occurred during the tests. Because the residuals had been landfilled, they contained a large number of rocks and other debris, which caused havoc with the ball mill. At one point, the tests were suspended so the larger debris could be screened out of the material. Future use of the material would require a screening device to remove large debris.

From a chemistry standpoint the tests showed that water treatment plant residuals would perform in this type of system. However, the economics of using the material on a full-scale basis would have to be weighed against the cost of excavating the material, transporting it to the plant and screening/conveying it to the FGD system.

Test #2 - Reuse of Newly-Produced WTPR in a Wet-Limestone FGD System

Test #2 was performed on an FGD system considerably different from the first. Some of the FGD characteristics and operating guidelines include:

- The coal has a sulfur content of 2.8 percent to 3.0 percent.
- High-purity limestone (greater than 94 percent $CaCO_3$ content) is required for proper performance.
- The reaction products are completely forced-air oxidized to produce a wallboard-grade material that is vacuum-filtered to produce a solid cake.
- Limestone is ground in wet mills set to produce a particle size of 80 percent passing through a 325-mesh screen.

The facility where this test was performed provides both electricity and water to a municipality. The water treatment plant blowdown is currently pumped to a storage pond located on utility property. Both plants are on the same site, so temporary piping was used to transfer blowdown from the water treatment clarifiers to the FGD system. An analysis of the residual solids and limestone is outlined in **Table 2**.

TABLE 1 Comparison of Residual Quality vs. Limestone Quality

Parameter	Residuals	Limestone
Weight Percent $CaCO_3$	82%	84%
Weight Percent Magnesium (as Mg)	0.9%	0.5%
Weight Percent Inerts	10.8%	14.5%

TABLE 2 Comparison of Residual Quality vs. Limestone Quality

Parameter	Residuals	Limestone
Weight Percent $CaCO_3$	75%	97%
Weight Percent Magnesium (as Mg)	4%	<1%
Weight Percent Organic Carbon	13%	NA

Prior to the test, both particle size and reactivity analyses were performed on pre-ground residuals and ground limestone. The geometric mean size of the limestone particles was 17 micrometers (μM), but the mean size of the pre-ground residuals was only 10 μM. The reactivity tests involved separate titrations of each material with sulfuric acid to determine the time needed for complete reaction while maintaining solution pH at 5.0. The limestone completely reacted in 150 minutes, but the residuals reacted in only 20 minutes.

Utility personnel were particularly interested in the full-scale test because the water-treatment plant storage pond has almost reached its maximum capacity. Dredging the pond is expensive. Limestone is also expensive because the utility purchases the stone from a quarry 120 miles away. Plant and consulting personnel estimated the utility could save between $100,000 and $300,000 per year with successful implementation of this program.

Results

The initial test was performed over a four-day period to allow the residuals to completely pass through the scrubber and waste-disposal system. Baseline and test data revealed:

- Reactivity of the reagent stayed constant, and calcium carbonate residuals in the waste product remained quite low at 0.5 percent to 1.1 percent by weight.
- No decline in SO_2 removal occurred.
- The material did not affect the performance of the oxidation system.

During the four-day test, foaming occurred in one of the main slurry vessels. Test personnel concluded the foam was caused by the organics in the WTPR.

Utility personnel have conducted a longer-term, follow-up test of this material and have discovered some additional problems. Most notably, after several days of operation, the vacuum drum filter cloth began blinding. An analysis revealed the blinding was caused by iron particles, most likely generated from the ferrous sulfate added at the water treatment plant for coagulation. The foaming problem also reoccurred. Excessive foaming could potentially influence scrubber operation, particularly if the foam reaches the mist eliminators. The foam might increase deposition within the eliminators or affect the mist eliminator efficiency.

Despite these difficulties, the utility plans further tests because the economic incentives are so great. Some possible solutions would be to switch to a non-iron-based coagulant at the water treatment plant, experiment with filter cloths of different pore sizes, and add an antifoam agent to the scrubber.

Conclusion

The use of water treatment plant residuals as a supplemental reagent in FGD systems has obvious economic and environmental implications. Furthermore, the material appears to be as or more reactive than even high-quality limestones. But, residuals do contain materials that can affect scrubber operation. Careful planning and testing of this type of program are very important. EP

Brad Buecker is a senior chemist at Burns & McDonnell in Kansas City, Mo.

For more information, circle 197 on card.

in print *Compiled by Ashley Blyth*

Check out some of EP*'s favorite catalogs, brochures, books and reports available this month.*

AN 8-PAGE BOOKLET ON "Theory and Application of

Kurz Thermal Convection Mass Flow Meters" provides an overview of CTA sensor circuitry, heat transfer equations, effect of fluid properties, time response to flow and temperature changes, and orientation effects. **Kurz Instruments Inc.**

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"SAMPLE INTRODUCTION Techniques for Capillary Gas Chromatography" helps readers quickly learn to use precision-programmed inlet systems. The 40-page illustrated primer describes the four injection techniques for liquid sample analysis: split, splitless, on-column and programmed temperature vaporization injection. **Gerstel Inc.**

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PETREX IS OFFERING A 4-PAGE brochure explaining how its aluminum honeycomb covers are system-engineered to eliminate vapor emissions and air pollution for Clean Air Act and EPA CFR Part 61 compliance. **PETREX Inc.**

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DISCFLO PUBLISHED A NEW 28-page brochure. It describes the operation of the disc pump and several case histories from pulp and paper manufacturing; chemical and petrochemical processing; oil, metal and mining; wastewater applications; and food processing. **Discflo Corp.**

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THE "SCOTT SPECIALTY GAS and Equipment Reference

Guide" contains more than 100 new pages of specialty gas products, gas-handling equipment, and technical and safety information. **Scott Specialty Gases.**

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LITERATURE DESCRIBING Fisher Tank's experience in manufacturing, modifying and repairing tanks for the petroleum, chemical, wastewater treatment, pulp and paper industries is available. Also outlined are tanks for water storage and fire protection. Two reference charts are included. **Fisher Tank Co.**

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SAFETY PRODUCTS FOR THE METALS industry are highlighted in Arbill's new catalog. Find gloves, clothing, respirators, eyewear, hearing and other safety products most often used in the metals industry. New products include the nitrile ultra-light glow and economy spectacles with wrap-around protection. **Arbill Industries.**

Circle 27 on card.

(Continued from page 13)

grow. This expensive bottleneck comes from the Clean Air Act Amendments of 1977 (sic). What future bottleneck will today's announcement cause?"

Amazon Deforestation Threatens More Than Plants and Animals

WASHINGTON, D.C.—The Amazon Basin, home to the largest rainforest in the world, is known for its astounding variety of plants and animals. But the rainforest may also be home to an even more overwhelming variety of previously unknown bacteria and this diversity, just as with plants and animals, may be jeopardized by deforestation, a report said in the July issue of *Applied and Environmental Microbiology*.

The report, by James Borneman and Eric Triplett of the Agronomy Department of the University of Wisconsin, Madison, describes a study in which soil samples were taken from a mature rainforest as well as an adjacent pastureland that was deforested. The soils were sampled using polymerase chain reaction (PCR) to isolate bacterial DNA.

The researchers identified 100 different DNA sequences, 98 from bacteria and two from another domain of microorganisms know as *archea*. Eighteen percent could not be classified in any known bacterial kingdom.

In addition to just examining and identifying microbial populations, the researchers also compared the populations of the two soil samples to illustrate the potential impact of deforestation on the microbial diversity of the soil in the region. "It's such a rich biological resource that we decided to go and study it," said Triplett. "In the discovery of new organisms we can find previously unknown enzymes that can help further the progress of biotechnology. In addition, there are bacteria out there producing antibiotics that we have yet to discover."

Pollution Reduction Program Receives Support

WASHINGTON, D.C.—Testifying July 10 before the Joint Economic Committee of Congress, Carlton W. Bartels, managing director of Cantor Fitzgerald Environmental Brokerage Services, supported market-based environmental trading systems as a "highly effective and efficient" government policy to integrate economic activity and environmental protection.

Bartels favorably contrasted tradable emissions programs to more traditional modes of implementing environmental policy, pointing out that "tradable programs can address the pertinent public policy of containing environmental impacts head-on while leaving the marketplace to obtain that goal."

He also urged that all future government-sanctioned emission credit program should be designed to refrain from inserting unnecessary complications into the system. "Markets work best when they are simple and unencumbered," he said.

Cantor Fitzgerald Environmental Brokerage Services is a division of a wholly-owned subsidiary of Cantor Fitzgerald, L.P., the world's largest broker of U.S. government securities, Eurobonds and sovereign debt. EP

new products

Water Treatment

The transportable AhlFloat™ Pilot Plant permits routine testing of chemical consumption, TSS, COD and color reduction at the mill site of pulp and paper mills to improve process control and spill containment and reduce water use. It processes 10 to 80 gpm of feed flow. **Ahlstrom Machinery Inc.**

Circle 198 on card.

Hydrogen Sulfide Removal

The SulFerox process, developed by Shell Oil and The

Dow Chemical Co., uses chelated iron solution to convert hydrogen sulfide contained in natural gas streams to elemental sulfur in a single step. It is an economical alternative to the traditional two-stage acid gas treating process requiring both an amine plant and a Claus unit. **The Dow Chemical Co.**

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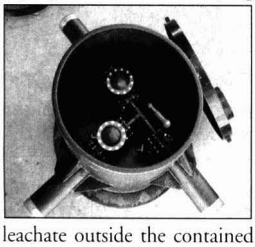
Leachate Recirculation

Fluid-Lok™ dual containment piping is ideal for carrying



leachate outside the contained landfull area. The Leak Detection and Location System continuous monitoring system sounds an alarm while a leak is recorded with accuracy of plus-or-minus 1 foot in 5,000 feet. It can be programmed to turn the pump off until corrective action can be taken. **Fluid Controls Inc.**

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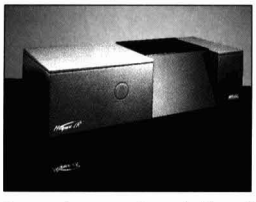
Spectrometer

The Prospect-IR™ is a durable FTIR spectrometer ideal



for routine sampling, dedicated analyses and educational applications. It fits in small lab spaces and is well-suited for field or portable applications. Comes with Windows™-compatible software. **MIDAC Corp.**

Circle 29 on card.

Flowmeter

The Model 310 Gas Flometer features an LED bar

graph display and an LCD digital readout. The 2.5-inch-tall, 20-bar graph meter is visible from up to 20 feet. It measures gas flow rates from 10 ml per minute to 200 liters per minute over several ranges with accuracy of plus-or-minus 3 percent full scale. **McMillan Co.**

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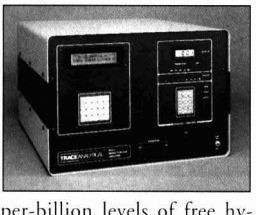
Groundwater Hydrogen

The RGA3 Reduction Gas Analyzer determines low parts-



per-billion levels of free hydrogen in groundwater. Field survey analysis takes four minutes. Released hydrogen indicates anaerobic bacterial activity from natural attenuation of halogenated solvents and petroleum pollutants. **Trace Analytical.**

Circle 31 on card.

Ultrasonic Measurement

Milltronics' HydroRanger non-contacting, ultrasonic

level- and flow-measurement system is designed for the wastewater industry. Applications include tank level measurement and complete lift station control. Its 33-foot operating range suits it to measurement throughout the wastewater treatment process. **Milltronics Inc.**

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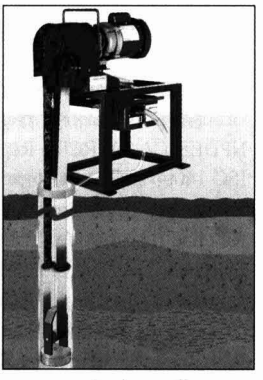
product exclusive

Belt Skimmers



The PetroXtractor has been improved in response to client suggestions. New system packages include underground installation, explosion proofing, high-capacity tail pulley and increased volume troughs. Three belt sizes are available: 1-, 2- and 4-inch. It monitors wells with casings as small as 2 inches inside diameter. Remove oil, fuel and other floating hydrocarbons from groundwater monitoring wells, recovery wells, underground tanks and other areas where access is limited and there is a deep drop between the well opening and the surface of the water. The belt comes in custom lengths and can reach depths of 100 feet. **Abanaki Corp.**

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Portable Labs

Hach's new CEL/800 Series Wastewater Laboratories are pre-

programmed to test for water quality parameters. Labs include aluminum, iron, nitrate, pH, phosphate and more. Each lab comes with all necessary instrumentation and reagents for comprehensive evaluation of wastewater. **Hach Co.**

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Chemistry Software

CAChe 3.0 is a software package for experimental chemists for Windows® 95 and NT. It includes ProjectLeader™ interface that lets chemists solve research problems by focusing on properties instead of complex computational methods. Chemists can explain activities of compounds, model reactions and predict a variety of chemical and physical properties for small molecules. **Oxford Molecular Group.**

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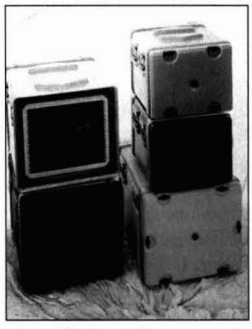
new products

Composite Cases

The Val-An Composite Series are constructed from



strong, lightweight composite materials to safely transport electronics and other sensitive equipment. Watertight cases are available in thousands of sizes with inner-panel options, a pressure-relief valve and a wide choice of colors. **ZERO Enclosures.**

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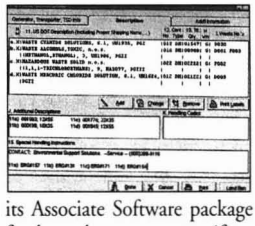
Hazwaste Software

Environmental Support Solutions releases Version 2.5 of



its Associate Software package for hazardous waste manifesting and tracking. New versions include better screen design, faster calculations, updated manifests for all states and improved databases. **Environmental Support Solutions.**

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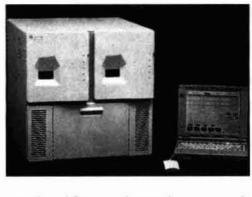
PC-Based Analyzers

The 9000 Series PC-based analyzers perform total nitrogen,



total sulfur and total trace sulfur determinations. Systems meet ASTM D4629, D5176, D5453 and D5762. They also are accepted by the California Air Resources Board (CARB) for low-level sulfur analysis in Phase 2 Reformulated Gasoline. **Antek Instruments Inc.**

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Field Calibrator

Calibration gas standards in the PPM ranges can be generated

easily and handled safely using the new Portable Field Calibrator and Dynacal gas permeation devices. Model 120 has a temperature-controlled chamber, internal pump, rechargeable batteries and certified flowmeter. **VICI Metronics Inc.**

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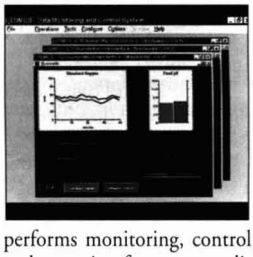
Water Quality Control

The Integrated Control and Instrumentation System (ICIS)



performs monitoring, control and reporting for water quality systems and a variety of other applications. It accommodates a wide variety of instrumentation equipment, monitors, sensors and devices. **WTC Engineering Inc.**

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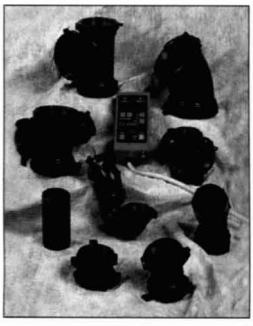
Piping System

The Fuseal™ II piping system's flame retardant compound is ideal for a wide range of conditions including corrosive chemical wastes, industrial plants, hospitals and university



laboratories. Pipe dimensions range from 1 1/2 to 12 inches. It handles corrosive drainage fluids up to 212 degrees Fahrenheit. George Fischer Inc.

Circle 40 on card.

Gas Detector

Gas detectors with configurations for ammonia, chlorine

and chlorine dioxide are available in the MicroMax series of gas detectors. They weigh less than 15 ounces and detect concentrations of oxygen, combustibles and up to two toxic gases. Lumidor Safety Products.

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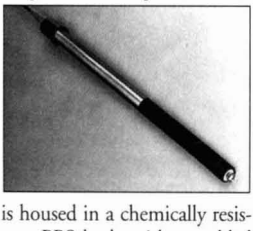
pH Sensor

The GT-DJ-GENIII-200mm long immersion pH electrode



is housed in a chemically resistant PPS body with an added 316 stainless steel extension tube for top- or side-entry installation. Rated for temperatures up to 135 degrees Celsius, it can be used for grab-sample measurements or mounted for on-line measurements. Innovative Sensors Inc.

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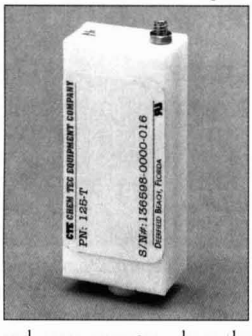
Flow Switch

The Teflon@ 125-T flow switch for industrial liquids



and gases operates where the normal flow-to-set point ratio is 10 to 1. When no flow is present, a free magnetic piston is suspended in the upper portion of the valve bore due to magnetic repulsion between the lower fixed magnet and the piston. CTE.

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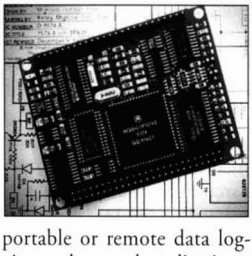
Data Logger

The TFX-11 is easily programmed for embedded



portable or remote data logging and control applications. Its non-volatile flash memory assures data integrity after power loss. Includes 19 analog input channels, 16 digital I/O lines, two processors, program memory, data memory and more. Onset Computer Corp.

Circle 44 on card.

Remote Monitor

The 560XI provides more input channels and generates a series of reports on operational performance. Ideal for users who need input monitoring rather than output control. It

SECRETARY OF THE COMMISSION
International Joint Commission, Washington, D.C.

The International Joint Commission (IJC), a bi-national organization established by the Boundary Waters Treaty of 1909 to help prevent and resolve disputes along the boundary between Canada and the United States, is accepting applications for the position of Secretary of the U.S. Section of the Commission. The incumbent serves as the senior civil servant and principal administrator of the U.S. Section, with responsibility for both the day-to-day management and direction of the organization as well as long-term planning, environmental policy development, and treaty and agreement implementation. Salary range for the position is $103,897 to $107,700. Some travel is required.

Applicants must possess and demonstrate extensive experience in all phases of organizational and program management, as well as substantive knowledge and expertise in environmental policy issues, legislative processes, and public policy development and implementation. Additional requirements include experience and skill in interacting with boards, commissions, or authorities, and the ability to collaborate and communicate with widely diverse organizations, groups, and individuals.

Prospective applicants should write to or call the IJC at 1250 23rd Street, NW, Suite 100, Washington, D.C., 20440, (202) 736-9000, to request a copy of the position vacancy announcement and application forms. Applications must be postmarked by September 30, 1997. The International Joint Commission is an Equal Opportunity Employer.

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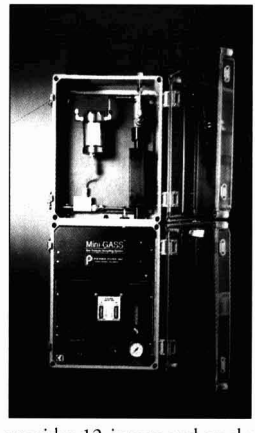
new products

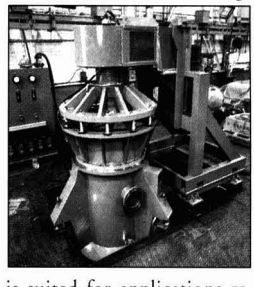


provides 12 inputs and tracks run-time meters, pulse totalization and pulse-rate monitoring. **Dancer Communications Inc.**

Circle 45 on card.

Vertical Centrifuge

The Sharples Super-D-Decanter® vertical centrifuge

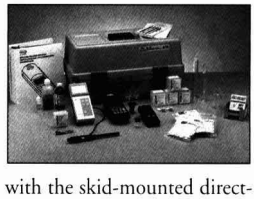


is suited for applications requiring containment of a process from the atmosphere including flammable, toxic, carcinogenic or pyrophoric materials. Operates at temperatures up to 700 degrees Fahrenheit and pressures from vacuum to 150 psi. **Alfa Laval Separation Inc.**

Circle 46 on card.

Thermal Fume Oxidizer

Destroy VOCs from a fume-laden exhaust stream



with the skid-mounted direct-fired thermal fume oxidizer with exhaust heat recuperation from Glenro Inc. It is 20-feet long, 10-feet wide and 7-feet high and comes pre-assembled. Includes insulated stainless steel ductwork. **Glenro Inc.**

Circle 47 on card.

BOD Meter

The new biochemical oxygen demand (BOD) meter

offers a 60-second method of estimating dissolved oxygen concentrations in unstirred water samples. The micro processor-controlled Model 200 is suitable for use in the lab or field. Includes an atmospheric pressure sensor. **Wheaton Science Products.**

Circle 48 on card.

Chemical Container

The 700-millimeter diameter stainless steel container is

custom-designed for closed-loop systems handling agricultural chemicals, hazardous materials and other industrial substances. Available in 60-, 100- and 119-gallon units. **Spartanburg Stainless Products Inc.**

Circle 49 on card.

Heavy-Duty Gloves

AEK™ work gloves for tough plant applications are

vinyl-coated and provide excellent grip. Ideal for assembly operations and general plant use. Features include a slip-on style cuff and reinforced thumb. They are machine washable with seams on the outside for comfort. **North Safety Products.**

Circle 50 on card.

Web Site

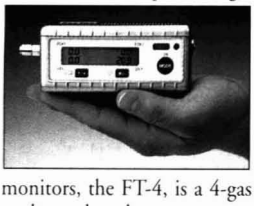
The H.L. Bouton Co. announced its new World Wide

Web site address and design at http://www.hlbouton.com. It provides Bouton's latest information on eyewear by styles and hazard, including impact, ultraviolet radiation, liquid splash and infrared radiation. **H.L. Bouton Co.**

Circle 51 on card.

Personal Gas Monitor

The newest member of the FoxTox Series of personal gas



monitors, the FT-4, is a 4-gas analyzer that detects oxygen, combustible gas and up to two toxic sensors. Toxic gas sensors are interchangeable and allow other sensors such as carbon monoxide, hydrogen sulfide, sulfur dioxide, nitric oxide and more. **Foxboro.**

Circle 52 on card.

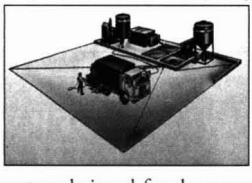
A-Rated Insurance

American Safety Casualty Insurance Co. expanded its environmental insurance program into Kentucky, Mississippi and Virginia on a licensed and admitted basis. It offers general, pollution, and umbrella liability to contractors, consultants, facility owners and labs for all remediation activities. **American Safety Casualty Insurance Co.**

Circle 53 on card.

Waste Management System

The Model WM[1] is a heavy-duty wash water recycling



system designed for the waste management industry. Intended for equipment cleaning operations associated with industries such as waste haulers, agricultural facilities, fisheries and military bases. **RGF.**

Circle 54 on card.

Sizing Software

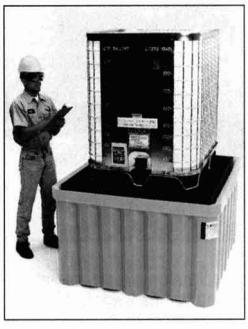
GoldSize 2.0 is a Windows-based software program that allows blasters to estimate the size distribution of particles produced from mining operation blasts. After photographing the particles, users process the photos and analyze the image in 20 minutes or less. **Golder Associates.**

Circle 55 on card.

Spill Containment

The Ultra-IBC SpillPallet offers 400 gallons of secondary containment to capture leaks and spills. The 100-percent polyethylene construction has

new products

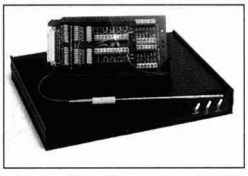


no metal parts to rust or corrode. Inner polyethylene supports have a 8,000-pound static load rating. Meets EPA Container Storage regulations. **UltraTech International Inc.**

Circle 56 on card.

Data Acquisition System

Add voltage and thermocouple measurement capability to notebook PCs for portable test applications and an alternative to plug-in boards for desktop

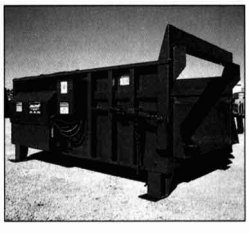


PCs with Omega's OMB-Tempbook-66. It provides 12-bit 100khz acquisition and transfer to a PC via an enhanced parallel port (EPP) interface or PCMCIA link. **Omega.**

Circle 57 on card.

Compactors

Marathon Equipment Co.'s self-contained and stationary

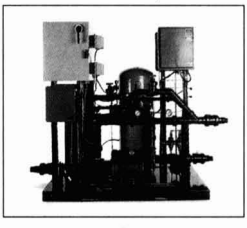


compactors became UL- and Canadian UL-listed. The structure, hydraulic and electrical systems have been tested and passed stringent inspection. They can be used for many types of waste applications. **Marathon Equipment Co.**

Circle 58 on card.

Ozone Water Treatment

The TurbOzone series of water treatment systems are



skid-mounted for easy installation and capable of treatment of cooling towers from 250 to 10,000 cooling tower tons. All models are complete with ozone generators, oxygen preparation systems, skid pumps, electrical panels and more. **Zentox Corp.**

Circle 59 on card.

Environmental Software

Automate environmental management and regulatory reporting goals with Enviro-Office™. It incorporates a suite of easy-to-use, Windows-based software applications that can be used on a stand-alone PC or on client/server networks. **Modern Technologies Corp.**

Circle 60 on card.

Remote Retrieval

The RMT 1000 is a remotely operated mast and claw that attaches piggy-back to VIT's ROVVER® 5.0 robotic crawler. Retrieve items from high-pressure power generation or manufacturing systems. **Visual Inspection Technologies Inc.**

Circle 61 on card.

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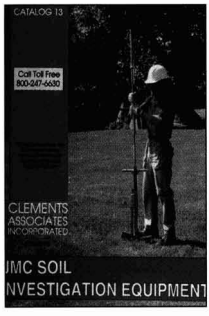
product literature



Clements Associates Incorporated manufactures a complete line of hand-operated soil sampling equipment. Their free 16-page catalog describes several probe handles, bucket augers, and sampling tubes with removable liners. It spotlights a probe that uses a sliding drop-hammer to drive a 36-inch long samplings tube into the ground and a foot-operated jack to retrieve it. With their equipment, samples as small as 1.2 inches in diameter up to 3 inches in diameter from 10 feet or more below ground level may be obtained. Equipment is sold as complete kits or individual parts. **Clements Associates Inc., 1992 Hunter Ave., Newton, Iowa 50208, Phone: 515-792-8285 or 800-247-6630, E-Mail: JMCSOIL@worldnett.att.net**

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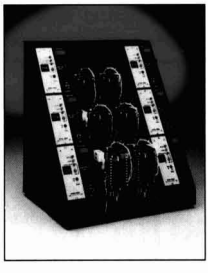

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Circle 155 on card.

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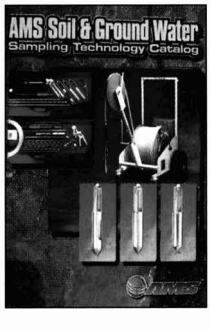

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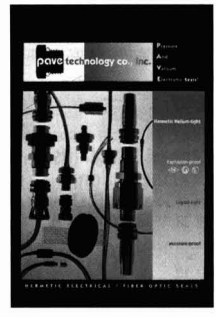

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Quanterra Environmental Services, 5251 DTC Parkway, Suite 415, Englewood, CO 80111. (800) 891-0188, FAX: (303) 796-2002.
Leader in environmental analytical testing, with nationwide network of laboratories.

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Phase One, 85 Argonaut #190, Aliso Viego, Ca 92656, (714) 457-0097.
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Permit Tracker Software, P.O. Box 3846, Indialantic, FL 32903-3846. (800) 365-3962, FAX: (407) 723-6213, Internet Address: http://www.macneillj.com.
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Environmental & Safety Services, Inc., PO Box 3394, Wilmington, NC, 28406 (910) 763-6999, FAX: (910) 763-8709.
Full service company specializing in OSHA and EPA training and consulting.
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SAMPLING SYSTEMS-WASTEWATER

Sirco Industrial LTD., Div. of Southwell Controls LTD., 857 W. 3rd St., North Vancouver, BC. v7p 1e3. (604) 980-3688, FAX: (604) 980-6578. Manufacturer of precision wastewater sampling systems for compliance monitoring programs.

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J.D. Meagher/Allwaste, Inc., PO Box 752, Westborough, MA 01581. (508) 366-6606, FAX: (508) 366-6662.
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T-4 Technology Inc., Suite 130, Box 10, 1187 Thorn Run Ext., Coraopolis, PA 15108. (412) 269-2709, FAX: (412) 269-2710.
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Apex Instruments, Inc., P O Box 727, 125 Quantum Street, Holly Springs, NC 27540. (919) 557-7300, FAX: (919) 557-7110.
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TANKS

Modutank, Inc., 41-04 35th Avenue, Long Island City, NY 11101. (718) 392-1112, FAX: (718) 786-1008. Low-Cost bolt-together modular tanks in all capacities, rent or buy.
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Rocky Mtn. Center for Occupational & Environmental Health, Bldg 512, SLC, UT 84112. (801) 581-5710, FAX: (801) 585-5275. E-Mail: crandall@ rmcoeh.utah.edu
Training in occupational & environmental health including lead & asbestos.

TRAINING/CONSULTING SERVICES

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Scientific Intruments, Inc., 518 W. Cherry St. Milwaukee, WI 53212. (414) 263-1600, FAX: (414) 263-5506, internet address: siis18@aol.com.
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❑ **YES,** I would like to receive/continue to receive **Environmental Protection.**

❑ **NO,** I'm not interested at this time.

Signature _____ **Date** _____

A. Which of the following Fans, Blowers & Aerator product(s)/services do you plan to purchase in the next 12 months? (Select all that apply)

800 ❑ Floating Aerators
801 ❑ Stationary Mount Aerators
802 ❑ Submerged Aerators
803 ❑ Tube Aerators
804 ❑ Centrifugal Fans
805 ❑ Aeration Blowers
806 ❑ Aeration Systems
807 ❑ Axial Fans

B. What is your reason for purchasing the selected products/services? (Select one)

808 ❑ New Construction
809 ❑ Plant Upgrade
810 ❑ Replacement/Maintenance

C. What is your projected budget for the selected products/services? (Select one)

811 ❑ Over $200,000
812 ❑ $100,001-$200,000
813 ❑ $50,001-$100,000
814 ❑ $10,001-$50,000
815 ❑ $5,000-$10,000
816 ❑ Under $5,000

D. How immediate is your need for the selected products/services? (Select one)

817 ❑ 0-3 months
818 ❑ 4-6 months
819 ❑ 7-9 months
820 ❑ 10-12 months
821 ❑ over 12 months

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4	35	66	97	128	159	190	221	252	283	314	345	376	407	438	469
5	36	67	98	129	160	191	222	253	284	315	346	377	408	439	470
6	37	68	99	130	161	192	223	254	285	316	347	378	409	440	471
7	38	69	100	131	162	193	224	255	286	317	348	379	410	441	472
8	39	70	101	132	163	194	225	256	287	318	349	380	411	442	473
9	40	71	102	133	164	195	226	257	288	319	350	381	412	443	474
10	41	72	103	134	165	196	227	258	289	320	351	382	413	444	475
11	42	73	104	135	166	197	228	259	290	321	352	383	414	445	476
12	43	74	105	136	167	198	229	260	291	322	353	384	415	446	477
13	44	75	106	137	168	199	230	261	292	323	354	385	416	447	478
14	45	76	107	138	169	200	231	262	293	324	355	386	417	448	479
15	46	77	108	139	170	201	232	263	294	325	356	387	418	449	480
16	47	78	109	140	171	202	233	264	295	326	357	388	419	450	481
17	48	79	110	141	172	203	234	265	296	327	358	389	420	451	482
18	49	80	111	142	173	204	235	266	297	328	359	390	421	452	483
19	50	81	112	143	174	205	236	267	298	329	360	391	422	453	484
20	51	82	113	144	175	206	237	268	299	330	361	392	423	454	485
21	52	83	114	145	176	207	238	269	300	331	362	393	424	455	486
22	53	84	115	146	177	208	239	270	301	332	363	394	425	456	487
23	54	85	116	147	178	209	240	271	302	333	364	395	426	457	488
24	55	86	117	148	179	210	241	272	303	334	365	396	427	458	489
25	56	87	118	149	180	211	242	273	304	335	366	397	428	459	490
26	57	88	119	150	181	212	243	274	305	336	367	398	429	460	491
27	58	89	120	151	182	213	244	275	306	337	368	399	430	461	492
28	59	90	121	152	183	214	245	276	307	338	369	400	431	462	493
29	60	91	122	153	184	215	246	277	308	339	370	401	432	463	494
30	61	92	123	154	185	216	247	278	309	340	371	402	433	464	495
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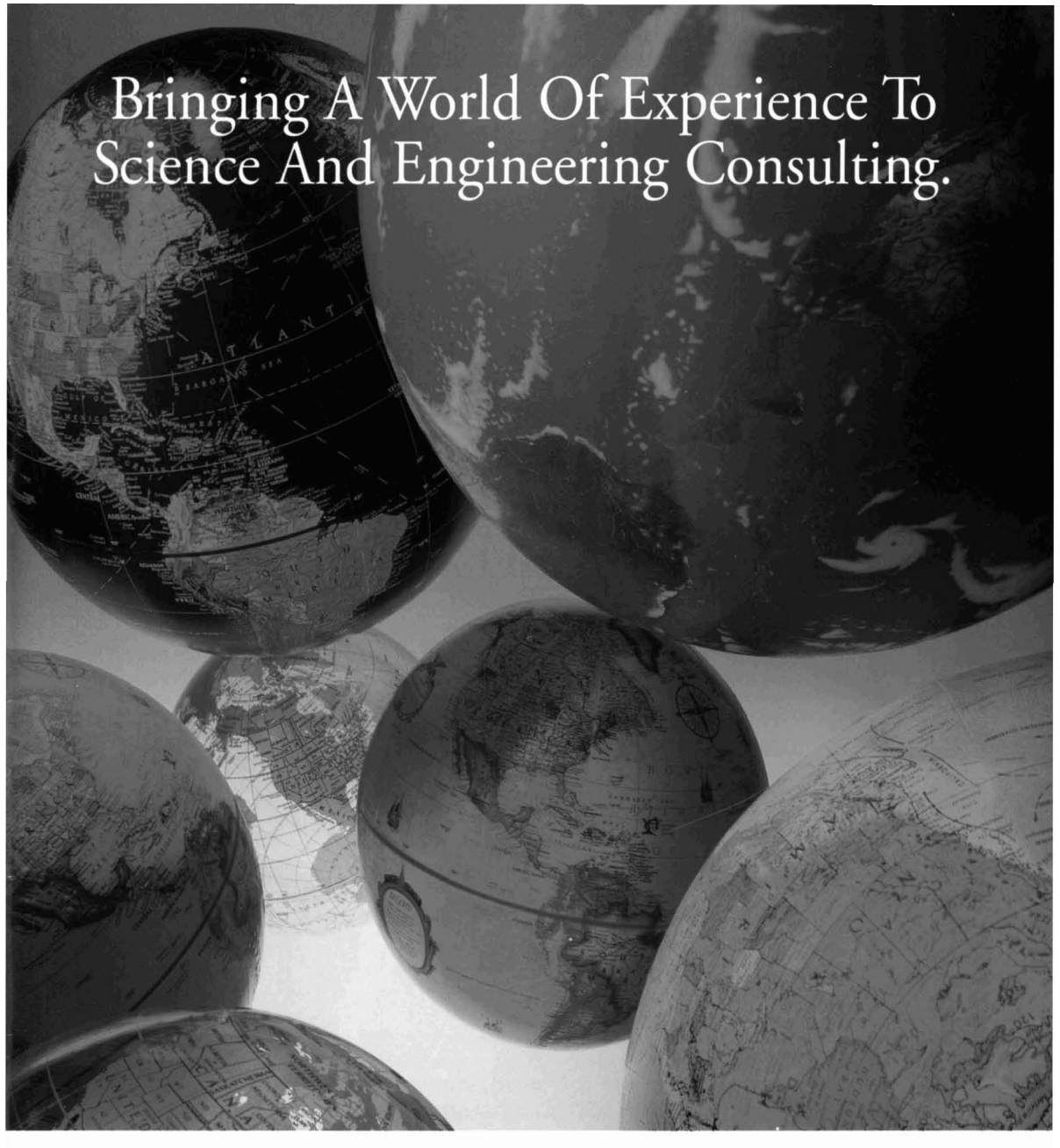

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