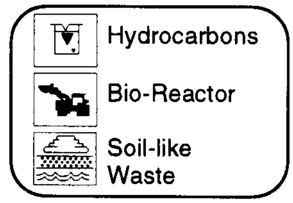
United States Environmental Protection Agency
Solid Waste Emergency Response (5102W)
EPA 542-N-94-004
May 1994

# TECH TRENDS

The Applied Technologies Journal for Superfund Removals & Remedial Actions & RCRA Corrective Actions

## Canadian Bio-Reactor Advances Knowledge of Hydrocarbon Remediation




By Alex Lye, Environment Canada, Groundwater and Soil Remediation Program, and Lin Callow, Canadian Association of Petroleum Producers

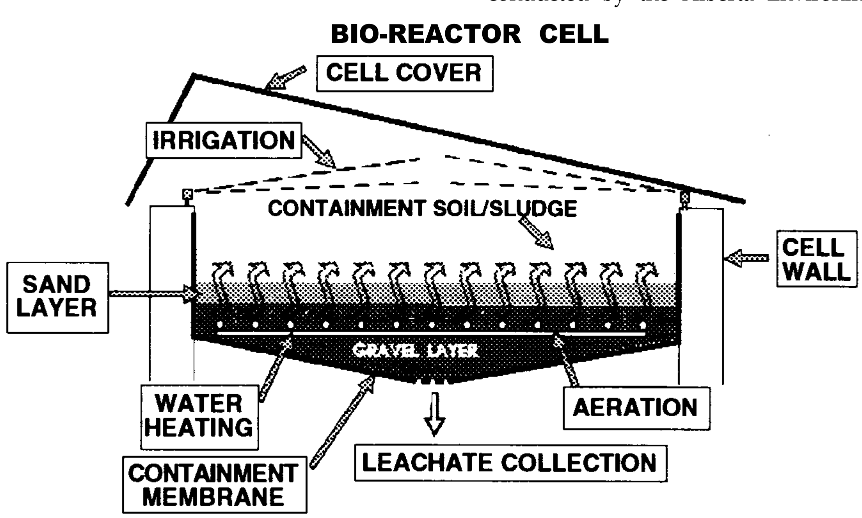
The Bio-Reactor Project tests the premise that hydrocarbon contaminated soils and soil-like wastes with high levels of salts can be treated effectively and efficiently by combining leaching with soil biological processes. To date, two types of wastes have been tested in the Bio-Reactor agricultural topsoil contaminated with crude oil and brine from a pipeline break (Waste 1) and saline diesel invert mud drill cuttings (hereinafter DIMR ) from a drilling site. Results from the first two years laboratory and field operations have demonstrated that the Bio-Reactor concept is viable. The project is co-funded by the Canadian Association of Petroleum Producers (CAPP); by Environment Canada through its contributions to the Development and Demonstration of Site Remediation Technology Program (DESRT), Groundwater and Soil Remediation Program (GASReP) and Federal Program on Energy Research and Development (PERD); and by the Alberta Environmental Research Trust. The research is conducted by the Alberta Environmental Centre in Vegreville and the University of Calgary. The Bio-Reactor is located at the Morrison Petroleums, Ltd. Nevis Sour Gas Plant.

### Picking Partners

**The emphasis of this issue of TECH TRENDS is on public-private partnerships that foster innovative technology. In addition to the Bio-Reactor Project article on this page, don t miss the article on EPA s Public-Private Partnership to Evaluate Innovative Technologies, on page 3.**

In contrast to landfarming of oily wastes, the Bio-Reactor exerts strict controls on all inputs, the physical-chemical environment and the fate of the transformed waste products. The Bio-Reactor can take wastes highly contaminated with oily wastes, that are not soil in the context of genesis, composition and function, and process them into stable soil-like solids with characteristics conducive to bioremediation and leaching. The wastes are thus processed in a soil-like environment with enhanced soil fertility, soil structure, soil chemistry and activity of soil organisms. Salts are removed by leaching prior to hydrocarbon reduction.

The Nevis sour gas plant provides essential services, such as heat, electricity, water and non treatable liquid waste disposal. In addition to using existing mixing equipment, a novel materials aggregator was developed. The Bio-Reactor was constructed consisting of nine cells in a linear array, each 3x10 meters (m), with independent controls for the following features: leachate containment and disposal (deep well injection); irrigation system to provide water, leach out salts and add soluble fertilizers; utilization of gas plant waste heat; forced




Schematic cross section of a Bio-Reactor Cell

*Bio-Reactor continued on page 2*

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# Fluid Extraction-Biological Degradation of Organics

By Annette Gatchett, Risk Reduction Engineering Laboratory

PAHs

Extraction & Bio-Reaction

Soil

EPA's Emerging Technology SITE (Superfund Innovative Technology Evaluation) Program has evaluated a pilot-scale fluid extraction-biological degradation (FEBD) process that remediates organic contaminants in soil. The system, developed by the Institute of Gas Technology, combines three distinct technologies: (1) fluid extraction, which removes the organics from contaminated solids: (2) separation, which transfers the pollutants from the extract to a biologically compatible solvent; and (3) biological treatment, which degrades the pollutants to innocuous end-products. The evaluation results show that the FEBD process was able to effectively extract 206 ring polycyclic aromatic hydrocarbons (PAH) at low temperatures and moderate pressures. Total contaminant concentrations in three different soil tests were 1925 micrograms per gram of soil for soil 1, 1504 micrograms per gram for soil 2 and 1969 micrograms per gram for soil 3. Soil 1, from a wood treatment site in Texas, was sandy with a 14% clay content. Soils 2 and 3, from two different gas sites, were almost entirely sand. The effectiveness of the extraction process was determined by following the fate of 16 compounds; and, examples of removal rates for extraction and biological treatment are given below.

In the fluid extraction step, excavated soils were placed in a pressure vessel and extracted with a recirculated stream of supercritical or near-supercritical carbon dioxide ($CO_2$). An extraction co-solvent increased removal of the contaminants. Extraction tests were performed in a supercritical fluid extraction unit. Soil 1 tests varied temperature, pressure, $CO_2$ to contaminant ratio and the addition of 5% methanol co- solvent. Temperatures were not varied in the extraction tests for soils 2 and 3. Clay in soil 1 did not appear to interfere with the extraction of the PAH contaminants. Increases in pressure and $CO_2$ and the addition of 5% methanol co-solvent increased extraction levels. The average 2 ring PAH extraction removal rates were 98.7% for soil 1, 50% for soil 2 and 99.4% for soil 3. The average 3 ring PAH extraction removal rates were 97.7% for soil 1, 89.5% for soil 2 and 99% for soil 3. The average 4 ring PAH extraction removal rates were 87.7% in soil 1, 82.2% in soil 2 and 97.9% in soil 3.

Following extraction, organic contaminants were transferred to a biologically-compatible separation solvent such as water or a water/methanol mixture. The separation solvent was sent to the final stage of the process, where bacteria degraded the waste to $CO_2$ and water. Biodegradation of the extracts ranged from 92% to 96%. Clean extraction solvent was recycled to the extraction stage.

Biodegradation occurred in above-ground aerobic bioreactors, using mixtures of bacterial cultures capable of degrading the contaminants. Selection of cultures was based on site characteristics. For example, for a site contaminated mainly with PAHs, such as the soils for this evaluation, cultures able to metabolize or cometabolize these hydro-carbons would be used. In this SITE evaluation, the microbial consortium effectively metabolized and transformed the PAHs in batch-fed and continuous feed reactors. Growth or metabolic activities of the microbial consortium were not inhibited by methanol extract.

For more information, contact Annette Gatchett of EPA s Risk Reduction Engineering Laboratory at 513-569-7697. Also, a summary report of the evaluation will be available by Fall 1994.

***Bio-Reactor continued from page 1***

subsurface aeration; tillage via a rail-mounted rototiller; and instrumentation to monitor moisture and temperature, and provisions to sample for oxygen, salts, oil content, carbon dioxide, volatile hydrocarbons and soil characteristics.

Waste 1, the crude oil spill in agricultural topsoil, arrived at the Bio-Reactor in a state totally unsuitable for leaching and bioremediation; it was a wet, oily, structureless mass of soil clods. To distribute the oil throughout the 40 tons of material, the waste was mixed by a hydraulically driven rototiller. However, the waste still lacked crucial features of arable soil structure and stability. Without structure, it could not be easily handled or leached, nor would it support biological activity. The aggregation problem was solved with the development of a specially designed aggregator; and, the aggregated material with N and P fertilizer was loaded into the Bio-Reactor to a depth of 15 centimeters (cm). The irrigation system was then used to rapidly leach out the salts (mainly NaCl); and, the degradation of the hydrocarbons was initiated by the native microflora. During the residence time in the Bio-Reactor, the oil content decreased substantially: and, the use of waste heat increased the losses of oil. However, oil losses were unaffected by forced aeration, likely because of good aggregation and a shallow treatment depth.

After 11 months in the Bio-Reactor, Waste 1 was transferred to a specially designed secondary treatment unit, the Bio-Pile. It is a simplified design

***Bio-Reactor continued on page 4***

# Public-Private Partnership to Evaluate Technologies

By Daniel Powell, EPA Technology Innovation Office

The U.S. Environmental Protection Agency (EPA), state environmental departments and other Federal departments are joining in partnerships with Fortune 500 companies to develop innovative treatment systems to address contamination problems of mutual concern. The goal of this public-private partnership concept is to obtain market, regulatory and public acceptance of innovative technologies through full-scale demonstrations of innovative hazardous waste treatment systems and treatment trains at Federal facility sites. The partnership will actively promote the use of less costly, environmentally sound technologies.

The public and private partners realize that there are benefits to pooling the expertise and initiative of EPA laboratories and State programs, other Federal research centers and private industries engineering departments. The effort can lead to faster identification and implementation of cost-effective, permanent treatment technologies and can encourage community acceptance of innovative alternatives to incineration through education.

The partnership is managed by EPA s Technology Innovation Office (TIO) and, through a cooperative agreement, is facilitated by Clean Sites, Inc. It brings together Fortune 500 firms, who are potentially responsible parties (PRPs) or operators of numerous Superfund and Resource Conservation and Recovery Act (RCRA) sites; Federal facility technology users: and regulators (EPA and States). The partners participate in technology selection, demonstration design and documentation of results. By including all of these parties from the earliest stages, full-scale cost and performance information on demonstrated technologies can be more easily transferred by both Federal and private parties to other sites.

The first partnership effort is now in the advanced planning stage at the McClellan Air Force Base site in Sacramento, California. The demonstrations at McClellan represent the pilot application of the public-private partnership concept. Partners at McClellan are EPA s Office of Solid Waste and Emergency Response, Office of Research and Development Risk Reduction Engineering Laboratory and Region 9; the State of California; the Air Force (Headquarters and McClellan Air Force Base): and seven private companies (Dow, DuPont, Monsanto, Xerox, AT&T, Beazer East and Southern California Edison).

Presently, the partnership is in the process of designing test plans for two demonstrations - a two-phase vacuum extraction system for treating organic contamination in the saturated zone and a photolytic destruction unit to treat off-gases from a soil vapor extraction system. The demonstrations should commence in August, with an opening ceremony to be held shortly thereafter.

In addition to two-phase vacuum extraction, the partnership may consider other ground water technologies for evaluation, including cometabolic biotreatment and high-energy electron irradiation. To address the off-gas that results from soil vapor extraction operations, three technologies in addition to photolytic destruction are potential candidates for evaluation - Purus Padre resin system, Carona Reactor electro-oxidation technology, and electron beam technology.

The performance and cost data collected at McClellan will be valuable components of technology transfer from one site to another. The public-private partnership can provide a more streamlined remedy selection process at other Air Force facilities and at the private company sites around the country, whose contamination problems may be similar to those found at McClellan.

In addition to the McClellan site, TIO is pursuing demonstrations at up to four additional Federal facilities, including sites operated by the Department of Energy (DOE), the Army and the Navy. Clean Sites and TIO are already in the process of working with DOE s Innovative Remediation Technology Demonstration Program to demonstrate innovative enhancements to a ground water treatment system at DOE s Pinellas, Florida facility. Clean Sites and TIO are also supporting the Remedial Technology Development Forum which will develop and test the Lasagna technology at DOE s Paducah, Kentucky Gaseous Diffusion Plant. The Lasagna technology uses hydrofracturing to place horizontal granular sheet electrodes and treatment zones in low permeable subsurface soil. Electro-osmosis is then used to move contaminated fluids through the treatment zones where biological or chemical activity destroys contaminants.

***For more information on the public-private partnership concept or the project, call Dan Powell in EPA's Technology Innovation Office at 703-308-8827 or Ellen Fitzpatrick of Clean Sites, Inc. at 703-739-1262. We will update you from time to time as the partnership progresses.***

*Bio-Reactor continued from page 2*

consisting of a single above-ground cell (10x12x1m) contained by a berm with a PVC liner, drainage collection system and dual controls for forced aeration, below ground heating and irrigation. Provisions were made to monitor oxygen, temperature and oil content and depth. The capacity of the Bio-Pile is 80 tons. No fertilization was necessary in the Bio-Pile; and, the oil degraded uniformly with depth. After five months of treatment in the Bio-Pile, the concentration of hydrocarbon content dropped from 2.6% to 2.2%. The beginning waste concentration was 4.3% prior to the initial treatment in Bio-Reactor. Toxicity testing conducted on the treated Waste 1 with 2.2% residual hydrocarbon content found no toxicity in: seed germination, root elongation, microtox, earthworm and algal test examinations. Plant yield tests are currently being conducted.

For the second test, a new rototiller was used which rode on the wails of the Bio-Reactor to precisely till selected cells without compacting the material. A high volume aggregator was designed and constructed. The second waste to be treated, the DIMR, required less pretreatment. In view of this, thorough examination of major factors affecting aeration were made in the nine test cells. These included forced aeration, tillage and aggregation in all combinations. Work on the DIMR was aimed to test long-held assumptions that tillage is beneficial and lack of aeration limits the degradation of hydrocarbons. All cells were heated to 30 degrees Centigrade, fertilized and irrigated as needed. Surprisingly, no major differences in hydrocarbon degradation could be attributed to the three treatments. During the four months of treatment, hydrocarbons decreased over 80% from an initial concentration of 10.8%.

The results from these two Bio-Reactor tests show that highly contaminated materials can be processed to produce stable soil-like solids with characteristics conducive to bioremediation. Tillage and forced aeration may not be necessary to achieve rapid oil degradation: but, hydrocarbon wastes can be rapidly degraded in heated units. Salts can be readily leached and disposed of using minimal quantities of water. Both the Bio-Reactor and the Bio-Pile can be operated 12 months of the year in the Alberta climate.

We will keep you informed of future B&Reactor developments, such as the results ofwaste 3 tests (flare pit sludge). For more detailed information on the Bio-Reactor Project, contact Alex Lye of GASReP at 905-336-6438. For progress reports and more detailed reports, contact Lisa Crichton at CAPP by phone at 403-267-1 100 or by FAX at 403-261-4622. There is a charge for the reports.

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