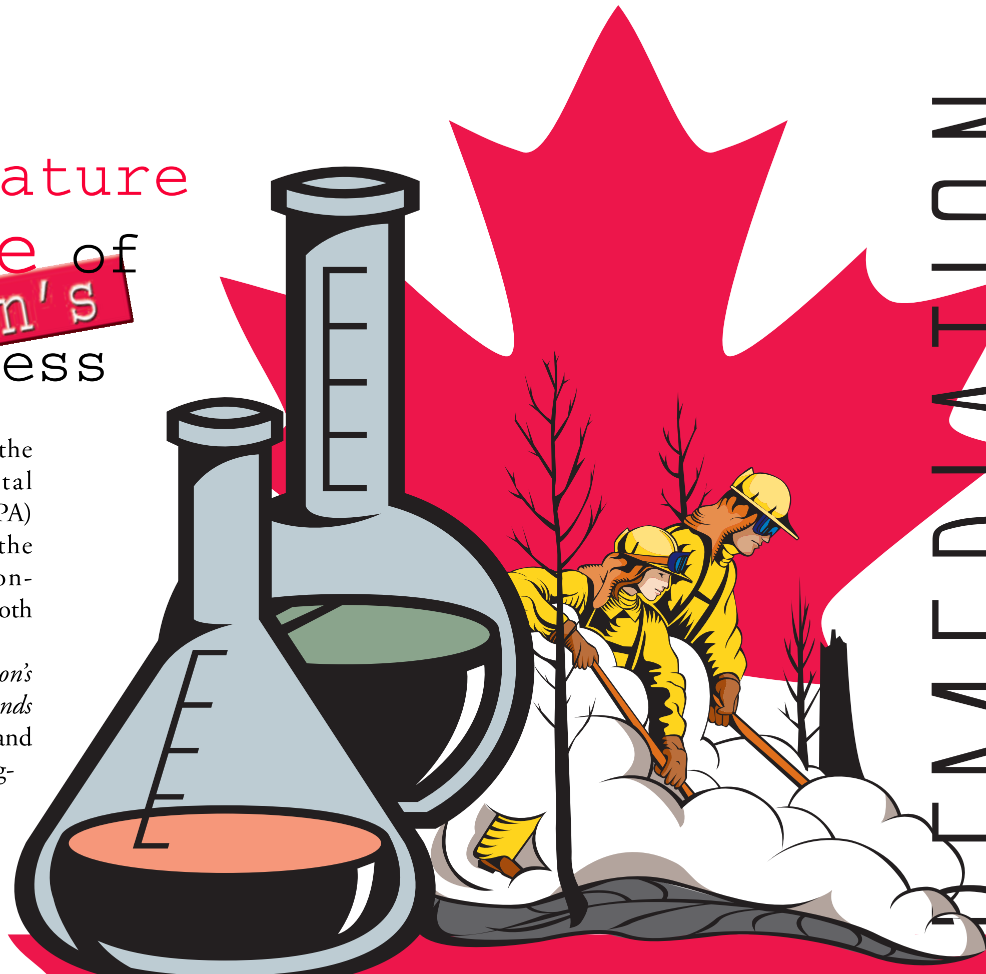
Helping nature take care of civilization's mess

BIOREMEDIATION



A chemical engineer at the University of Toronto is leading exciting research into the use of organisms to break up harmful contaminants in soil and groundwater. With contaminated sites becoming more of a hot-button issue in North America, research into bioremediation is sure to become more important to the engineering community at large.

By Michael Mastromatteo

A recent report from the U.S. Environmental Protection Agency (EPA) is certain to catch the attention of environmental engineers and consultants on both sides of the Canada-U.S. border.

The report, *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends* (2004), suggests that private entities and taxpayers in the U.S. could face a staggering $250 billion price tag to clean up more than 350,000 contaminated sites between now and 2039. The sites range from former military bases, to Brownfields industrial areas, to something as ubiquitous as dry-cleaning operations. In the latter case, the improper disposal of chlorinated solvents used in dry-cleaning outlets has given rise to groundwater contamination concerns that are only slowly coming to the attention of policymakers and the public.

In Canada, the emphasis on identifying contaminated sites and working to bring them back to some form of productive use hasn't gained the same sense of urgency as in the U.S. Nonetheless, many environmental consultants believe that the number of contaminated sites in Canada and the U.S. is much higher than either government knows of, or is willing to admit.

With a renewed emphasis on Brownfields redevelopment, and the generally increased awareness of harmful chemicals lurking in soil and groundwater, efforts to identify contaminated sites and to prioritize cleanup operations are expected to increase significantly in the coming decades. Such efforts will present commercial opportunities for environmental engineering consultants, but they will also bring challenges to the profession in general to help evaluate the most innovative and cost-effective remediation technologies.

One engineer who has made significant progress in advancing groundwater and soil remediation strategies is Elizabeth Edwards, P.Eng., of the University of Toronto's department of chemical engineering and applied chemistry. The Montreal expatriate leads a research laboratory dedicated to studying the role biological processes can play in environmental amelioration. Her work is gaining notoriety for its examination of the biodegradation, biotransformation and bioremediation of organic pollutants.

Tweaking nature

Despite the heavy dose of polysyllabic terms, Edwards' work might be more readily understood as "tweaking nature" to come up with environmentally benign organisms designed to break down harmful compounds in soil and groundwater. She is involved in studying if such organisms already exist in nature, taking note of their composition, and working to cultivate them in laboratories for widespread use in contaminated site cleanup.

Although much of her research focuses on chlorinated ethenes, such as perchlorothene (PCE) and trichloroethene (TCE), Edwards is also involved in studies of the transformation of other chemical substances, such as petroleum hydrocarbons, in ground and surface water. Another line of research aims to detect "endrocrine disrupting substances" in the environment. This involves the use of DNA microarrays to look for gene patterns that could yield clues as to the minute effect pollutants may have on organisms.

Nonetheless, research in the degradation of chlorinated solvents is what is now yielding more dramatic results. Chlorinated compounds are widely used as degreasing agents in dry cleaning, manufacturing and semi-conductor industries.

As she describes to visitors to her U of T website, "a fundamental understanding of biological degradative processes occurring in groundwater is essential to the proper application of bioremediation or bioaugmentation."

Edwards' research efforts have been supported by the Natural Sciences and Engineering Research Council (NSERC) in Ottawa, the U.S. Department of Energy (DOE), and GeoSyntech Consultants in Guelph. The central thrust of her work involves understanding how biological processes impact on the "fate" of pollutants in the environment. Working with team members, Edwards applies a variety of methods from chemistry, molecular biology and microbiology to unravel and rebuild complex microbial processes.

Bioremediation is seen as a favourable alternative to more costly and disruptive technologies, such as the traditional dig and disperse, or pump and treat methods.

One key research goal is to understand how organic contaminants are "biotransformed" by anaerobic microorganisms in subsurface environments. As such, Edwards and her team have found "novel biodegradation pathways" that have proven effective in field trials, primarily in the U.S.

Edwards outlined key elements of bioremediation work at a January 2005 presentation at the University of Toronto. One of the key points made is that some chlorinated contaminants behave differently in the presence or absence of oxygen (aerobic/anaerobic). Chlorinated solvents, such as PCEs and TCEs, generally remain stable in the presence of oxygen. Under normal conditions, these compounds transform in soil and groundwater to the more harmful vinyl chloride end product. Edwards has noted that under reduced oxygen conditions, these compounds are susceptible to "sequential dechlorination," which means that with the introduction of a dechlorinating catalyst, these compounds pass from a toxic to a non-toxic state.

Edwards seeks to cultivate organisms that maintain and abet the process so that PCEs/TCEs are more readily transmuted into harmless ethene.


Chemical engineer Elizabeth Edwards, P.Eng., at one of the anaerobic chamber facilities at her University of Toronto laboratory. Edwards is involved in exciting research aimed at cultivating natural organisms that assist in the break-up of contaminants in soil and groundwater.

Commercial application

Her lab has since produced a culture, dubbed KB-1, which is being prepared commercially for use as a large-scale bioaugmentation agent.

Although Canada is lagging behind the U.S. in the study of bioremediation technology, a few Canadian-based organizations have noted their potential. Edwards believes this commercial dimension could prove beneficial to environmental engineers offering remediation services. "There will always be a market for engineers in the remediation business," Edwards said. "What we need to foster is not simply a desire to sell services and make money, but also a genuine incentive for companies to clean up the environment. Sometimes, consultants are simply playing games to delay legal battles or buy time from regulators and save clients' money, rather than to sensibly address the environmental issue. Also, some regulators sometimes just take a hard line, and don't consider all the aspects of a particular problem, and the difficulty a company might have in meeting cleanup criteria without going bankrupt."

While Edwards is keen to advance research efforts into bioremediation, she also believes environmental engineers should be at the forefront in advising government policymakers as to the most cost-effective cleanup activity. And, given concerns about the under-reporting of present-day contaminated sites, establishing a priority list for more immediate action should be high on the agenda.

"Because the cleanup of contaminated sites is costly, and because effective remediation strategies don't currently exist, we're hoping bioremediation will gain more acceptance," Edwards told *Engineering Dimensions*. "Prioritization is critical, since there are not sufficient resources. Also, we need to better promote alternative and less expensive cleanup options, even if they don't result in meeting the cleanup standards set at a particular site, since some cleanup is better than none–at most sites anyway. Bioremediation often falls into this category, where the time it takes and cleanup levels are possibly not as good as with other technologies, but it is a lot cheaper. We also need to promote trials of alternative technologies in general. Canada does not do this that well and, as a result, most new technologies are being developed in the U.S."

Having government policymakers sit up and take notice of bioremediation technologies is only half the battle. As such, Edwards also finds motivation for her research into bioremediation in considering what she terms the "legacy of contamination" built up in the decades prior to more effective environmental regulation.

Edwards believes a multi-disciplinary effort on the part of engineers, chemists, hydrogeologists and researchers would play a major role in expanding the bioremediation frontier. Future challenges for researchers include the discovery of organisms that might accelerate the breakdown of more problematic substances, such as polychlorinated biphenyls (PCBs), dioxins, and fluorinated compounds (Teflon).

"Ideally, we can mine the diversity," Edwards said. "With the zillions of bases of sequence information, we will be able to perform massive screens for enzymes with undisclosed catalytic activity."