BOOK REVIEW

Bioremediation is making slow, steady progress

Bioremediation Principles and Applications by Ronald L. Crawford and Don L. Crawford (eds.), Cambridge University Press, Cambridge, UK, 1996.

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If ever a problem deserved be the highest priority of U.S. policymakers, it is the massive job of cleaning up the nation's toxic and hazardous waste sites. According to a report from the Environmental Protection Agency (EPA; Washington, DC), "Cleaning Up the Nation's Waste Sites: Markets and Technology Trends," more than 200,000 contaminated sites across the country will require some $187 billion to clean up under current U.S. laws—a conservative estimate, even by the EPA's lights.

Since the 1980s, a plague of questions has undermined the nation's commitment to cleaning up this legacy of 20th century industrialism. Researchers have raised legitimate questions, not only about the shortcomings of data on the actual toxicity to humans and the environment of many commonly used industrial contaminants, but also about the high cost and effectiveness of so-called zero-risk environmental cleanup technologies, such as incineration and landfilling.

The subsequent erosion of public concern, of course, does not mean toxic chemicals and hazardous waste in the environment do not pose serious threats to human health or the environment. Quite the contrary. In fact, the shifting foundations of environmental science and technology have set off a rush to find new methods for cleaning up potentially deadly industrial contaminants with a greater degree of effectiveness and at substantially less cost than older remediation technologies.

Among the most promising of these innovative technologies, of course, is bioremediation, as we have been hearing since it gained widespread publicity in the aftermath of the 1989 Exxon Valdez oil spill in Alaska. Hence the potential importance of *Bioremediation Principles and Applications*, which is part of the Cambridge University Press's Biotechnology Research Series and the first real tour d'horizon of the history and science of bioremediation. Edited by Ronald L. Crawford and Don L. Crawford, researchers, respectively, at the University of Idaho's Center for Hazardous Waste Remediation Research and its Department of Microbiology, Molecular Biology, and Biochemistry, the result is an informative, if highly technical, account of the progress that has been made in the field in the past 25 years.

With chapters on everything from ubiquitous petroleum contamination, remediation of polycyclic aromatic hydrocarbons, the anerobic bioremediation of BTEX hydrocarbons, to a history of PCB biodegradation and the microbial remediation of metals, the editors have brought together some of the top researchers in the field in a heavily footnoted, comprehensive compendium of research literature that, unfortunately, will prove at best hard slogging to anyone but fellow researchers.

Even so, the Crawfords have attempted to couch the collection of bioremediation research in the context of the emergence and expansion of the bioremediation industry. They assert, without anything but the most circumstantial of evidence, that "Bioremediation is becoming the technology of choice for the remediation of many contaminated environments, particularly sites contaminated by petroleum hydrocarbons."

They also note studies confirming the economic advantages of biotreatment of biodegradable hazardous wastes. In general, significant cost benefits have been credibly postulated before. But the numbers cited by the editors estimate that bioremediation of polluted soil costs between $40 and $100 per cubic yard, compared to conventional costs of $250 to $800 for incineration and $150 to $250 for disposal in landfills. In a market with a standing pricetag of $200 billion, that is real economic leverage.

The editors appear to have selected researchers mindful that the best bioremediation science may amount to very little without engineering systems that can effectively deliver the medicine. In situ bioremediation techniques, which are receiving much attention from researchers these days, may avoid expensive excavation of contaminated soils or notoriously inefficient pump-and-treatment systems for polluted groundwater.

Yet in situ bioremediation technologies are still far from efficient degraders of contaminants. The reasons are manifold, from wells and tight spots in aquifers that become clogged with microbial growth to the human failure to supply sufficient oxygen or other chemical nutrients to stimulate growth of contaminant-eating microbes.

Interestingly, there is some evidence that the biochemistry and engineering of bioremediation are becoming increasingly blurred. The fact that some chemical pollutants, such as trichloroethylene (TCE), a common industrial solvent, are not readily degradable by microorganisms has led to research in co-metabolism, a process by which pollutants are degraded by enzymes used by microbes to break down substances that in turn stimulate microbial action. These co-metabolic pathways have proven effective enough that researchers believe they may be harnessed to attack other classes of contaminants in the future.

Other developments, such as the encapsulatation of pure microbial cultures in small beads to deliver unique microorganisms into underground aquifers, are equally intriguing. But since many industrial pollutants are not degradable by known, naturally occurring biological processes, the most rapidly developing potential for bioremediation is still the use of genetically engineered microorganisms. Ron Untermann, chief of research for Envirogen (Lawrenceville, NJ), has contributed a chapter detailing the scientific history of PCB biodegradation that is a must-read for anyone interested in the future of bioremediation.

Crawford and Crawford straightforwardly acknowledge that, in too many cases, bioremediation research efforts over the past several decades have been beset by duplication and wasted energy. They are equally blunt in acknowledging that the bioremediation business has suffered from overselling. They staunchly maintain, though, that research gains are now changing the status quo. "Some of the world's best scientists are using their skills to design experiments that lead to a better understanding and tighter control of biodegradative processes," writes Ronald Crawford. "The role for bioremediation in environmental restoration is steadily increasing."

Perhaps. But that does not dispel a suspicion that this insider's view consigns greater importance than is warranted to a promising, but still largely unproven, technology. Unfortunately, the fate of bioremediation probably hangs on the answers to the larger questions that have eroded public interest in the toxic and hazardous waste problem itself. How do you measure the toxicity of industrial contaminants? At what levels do toxic chemicals harm human health and the physical environment? In the end, how clean does clean have to be? What will it cost?

The editors do not address how the new science of bioremediation may affect the answers to those questions. Unless a consensus emerges on the benefits innovative technologies like bioremediation bring to toxic and hazardous waste cleanup, the flow of political and financial capital for research and development is likely to remain modest. ///