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Guest editorial

Bioremediation is the use of microorganisms to mitigate hazards of soils or groundwater contaminated with organic waste materials. The technology has been receiving increased attention over the past 6–8 years due to a number of reasons, not the least of which, is the lower cost of environmental reclamation of contaminated sites. With the impact this technology is having on the science of microbiology, the editors of *Biodegradation* proposed to present a special issue on some of the significant areas of successful application, new developments in the field, and future technologies now in the laboratory.

Biological degradation of organic waste can, and usually does, result in complete destruction of the contaminants and elimination of future liability to the responsible party. As the number of contaminated sites increase and the number of options such as landfilling decrease or become more expensive, bioremediation has become more popular and subsequently more widely used. However, as the popularity of using biological treatment increase, the pressures for performance beyond developed capabilities also increase. It has long been realized that microorganisms are capable of metabolizing naturally occurring organic compounds. However, many problem environmental sites also have xenobiotic or synthetic compounds which may or maynot be biodegradable. This latter phase has been the focus of much microbiology research in the laboratory for the past few years. However, field developments have primarily focused on the application of previously developed science on the biodegradation of naturally occurring organic compounds such as petroleum waste products. This special edition of *Biodegradation* describes some of the typical applications in which bioremediation has been successfully used to cleanup contaminated soils, some recent developments in application technologies and a brief examination of some of the most recent molecular developments which bear on future bioremediation technologies.

One of the difficulties facing the increased commercialization of bioremediation is the lack of reliability in laboratory to field data transfer as well as the inability to transfer from one field site to another. Of course, biological systems are dynamic and in nature are constantly changing with their environment. The result is today most treatability studies and field scale up experiments are done on a site specific basis. This lack of reliable field or site linkage severely hampers commercial-scale operations. Blackburn et al. thoroughly address this problem and describe a number of physical, chemical, biological, analytical, and statistical issues regarding the successful comparison of results between experiments and field data. The paper includes descriptions of experimental designs and potential problems due to sampling frequency or types. The authors fully describe many areas from field characterization to field pilot studies where differences in design and analysis result in difficulties in linkages which would make the data generated more transferable. Solutions to reliable linkage problems are left to the reader to resolve.

Almost a cottage industry of the bioremediation market is the sale of biological seed cultures for the enhanced biodegradation of everything from diesel fuels to PCBs. However, little or no evidence has been offered in the peer-reviewed literature or even in the 'grey' literature which supports the claims that bioaugmentation is any more effective than indigenous microflora. While seed or starter cultures do have benefits in reducing lag phases of bioreactors, the cultures are most often replaced by indigenous microflora within a short time. On the other hand, field inoculations of open systems have had only limited success with few documented cases.

Although many practioners have implemented clean up of many different types of sites in the USA, few of these remediations have been adequately monitored and reported. This lack of credible information also contributed to the slow growth of the industry. Laboratory and pilot scale studies are important factors in the commercialization of bioremediation, but full scale successful reclamation of large quantities of contaminated soils with scientifically validating monitoring data is one of the most important developments in this emerging field. A large successful bioremediation project would include monitoring data on the biological processes which continuously reveal the current status of the biological health of the system as well as the chemical monitoring data. The success of a project is somewhat dependent on the integration of multi-disciplinary expertise in the field. The problems associated with the implementation of bioremedial technology for petroleum hydrocarbon contamination are significant. The integrated expertise of engineers and scientists including chemists, microbiologists and hydrogeologists, will ultimately decide the success of many field projects. We must endeavor to continually improve our ability to perform (engineer) good science in the field. Unfortunately, none of the full scale remediation papers arrived in time for inclusion in this edition. It is equally important for the continued development of bioremediation that scientific documentation of successful field projects be published.

Much attention is also being given to the bioremediation of other more recalcitrant contaminates. These chemicals often pose more interesting science problems to research microbiologists than field implementation problems with existing science. Tiedje et al. thoroughly describe the reductive dechlorination processes and the problems associated with implementation of PCB bioremediation processes. Anid, Ravest-Webster, and Vogel report on the laboratory demonstration of PCB biodegradation in microcosms containing contaminated Hudson River sediments illustrates more recent scientific discoveries implemented in a complex system. The authors examined the potential to aerobically stimulate the bioremediation of previously anaerobically dechlorinated PCBs in laboratory system. The results showed a removal of over 85% of total PCBs resulting in the reduction of sediment PCB levels to less than 20 mg/kg. The results support the potential for in situ biodegradation of PCBs using a sequential anaerobic-aerobic technique as previously reported.

Our understanding and developments in anaerobic biodegradation techniques is progressing rapidly. The increased emphasis on this research has opened a number of new possibilities for environmental reclamation techniques. Much of the recent field work on BTEX degradation under nitrate reducing conditions is not covered in this edition. However, a number of field projects have been completed evaluating the utility of nitrate reducing systems in aquifer reclamation. Mikesell, Kukor, and Olsen report on the microbial ecology or the metabolic diversity of hydrocarbon degraders found in BTEX contaminated aquifers. They isolated large numbers of broad range aromatic hydrocarbon degraders under hypoxic conditions with nitrate as an electron acceptor and even a nitrate dependant aromatic hydrocarbon utilizer. The authors propose that isolation conditions influences the substrate range obtained from environmental samples. They also propose that in situ strategies may require less oxygen than assumed to be necessary if nitrate is present as an electron acceptor.

Much has been published in recent years concerning the biodegradation of chlorinated aliphatic solvents such as trichloroethylene, TCE. However, little field demonstration data is available for the implementation of this information. Many problems are associated with the scale up of liquid phase bioreactors due to competitive inhibition for the inducing substrate. Most reactors result in selecting for strains which do not biodegrade TCE. Dolfing, van den Wijngaard, and Janssen review the mechanisms of microbiological degradation of this group of chemicals and examine their removal from air streams. They present the advantages and disadvantages of various bioreactors and the bacterial strains known to biodegrade TCE and other chlorinated solvents. J. van Groenestijn and Paul Hesselink further review biotechniques for the removal of air contaminants. They describe this technology which has developed quite rapidly in the EEC but has only recently begun to be applied in the USA. They describe the latest developments in which the techniques and designs are ever improving with the growing insights into the kinetics and microbiology of these reactors. Early developments were made in undefined systems in which good elimination efficiencies were achieved but these were not reliable for the long term. However, the comparatively low cost of construction and operation has driven the concept and new developments to obtain large and more efficient units in the field.

For the most part, traditional counting methods and enrichments are used to enumerate catabolic capabilities in the field and to evaluate soil samples for the potential capacity for biodegradation of specific contaminants. Few new methods are available and those that are available are too expensive for widespread application in bioremediation projects. Molecular techniques using genetic probes or molecular indicators have not been used in environmental soil systems to evaluate the genetic potential of these environments. Sanseverino et al. examined the use of the lux reporter gene to determine bioavailability of PAHs in soils as well as gene probes to determine genetic capacity of these environments. The laboratory microcosm data yielded valuable information on the in situ populations without isolation techniques. This field will probably develop rapidly and provide new insights for rapid detection of metabolic potential in an open environment.

This special edition covers many current bioremediation advances from field reclamation to laboratory developments for future applications. While not all the invited papers were received in time for publication, those provided reflect the growing industry and field developments for this science. This publication serves to emphasis the importance of continued development and integrated multi-disciplinary approaches to further advancing this science and to achieving more efficient and less costly environmental remediation of contaminated soils and groundwater.

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