Volume II
Biodegradation
Technology Developments

BIOREMEDIATION: Principles and Practice

Volume II

Biodegradation Technology Developments

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To the memory of Arthur Winston Busch, 1926–1994: Arthur W. Busch served as Professor Irvine's mentor from the moment that they met. His thoughts and ideas created an atmosphere which fostered creative research and development. The Sequencing Batch Reactor (SBR) is a technology that emerged from this environment and a technology which demanded fundamental understandings from science and creative applications from engineers. Art Busch's memory serves as a beacon lighting a path on which challenge will bring us closer to truth.

To Professor Alan D. Randolph, who despite severe physical difficulties imposed by multiple sclerosis still keeps his mind engaged in the pursuit of advancing the science and engineering analysis of particulate processes, in which field he is the most significant pioneer. Subhas K. Sikdar fondly remembers the graduate research experience under Professor Randolph, who still remains an inspiring figure in his (SKS) quest for innovative solutions to engineering problems.

Preface

This three-volume series, *Bioremediation: Principles and Practice,* will provide a state-of-the-art description of advances in pollution treatment and reduction using biological means; identify and address, at a fundamental level, broad scientific and technological areas that are unique to the subject or theme and that must be understood if advances are to be made; and provide a comprehensive overview of new developments at the regulatory, desk-top, bench-scale, pilot-scale, and full-scale levels. The series will cover all media—air, water, and soil/sediment—and will blend the talents, knowledge, and know-how of academic, industrial, governmental, and international contributors.

Developing this series has been a lengthy process because of the size of the project and because of the standard of excellence that has been set. We wish to thank the Technomic Publishing Company for its support throughout the process.

Glancing through the tables of contents, you will see that our objective for this series was to provide the theoretician and practitioner with an overview of bioremediation that will allow new research programs to be formulated and bioremediation technologies to be improved. This series is intended for the student and consulting engineer and the scientist and industrialist alike. Accordingly, we have addressed the removal of both hazardous and nonhazardous contaminants from the liquid, solid, and gas phase using biological processes. This includes the biological treatment of wastes of municipal and industrial origin; bioremediation of leachates, soils, and sediments; and biofiltration for contaminated gases.

As you read through many of the excellent chapters, you may wonder why some chapters were selected. In fact, one chapter that did not make the publisher's desk is one that dealt with incineration. We wanted a chapter on incineration so that we could better demonstrate, by contrast, how and when bioremediation is the appropriate choice. But as was the case with several other chapters, we simply could not convince the best authors to prepare chapters for what they perceived to be unrelated topics. Because of that, we would like to add a few words here about biological processes.

As we all know, microorganisms will grow if provided the proper conditions. In fact, it is often difficult to stop microorganisms from growing. Consider your soured milk, moldy week-old bread, or slippery shower room floors as examples. In fact, if you put a match to a substance, place your hands over the resulting flame, and keep your hands warm, that substance is very likely biodegradable, even if someone has labeled the substance as hazardous! The best that we can determine, unless the substance is drinking alcohol or rubbing alcohol, is that the compound is likely to be found on one hazardous substance list or another or that someone simply forgot to put it there.

Microorganisms need a carbon and energy source. As just discussed, both hazardous and nonhazardous contaminants satisfy either or both of these requirements. The design engineer must ensure that all of the necessary ingredients are supplied in sufficient quantities during any bioremediation project. Just like the grass on our public golf courses, microorganisms need nutrients such as nitrogen, phosphorus, and trace metals. Aerobic organisms need a source of oxygen. The temperature and pH must be controlled as needed, and sometimes, substances that are toxic to the organism (e.g., heavy metals) must be removed. In general, it is not difficult for the designer to engineer a system that will meet all of these requirements for the biological treatment of contaminated liquids, soil or sediments, and gases.

A basic messsage is that most hazardous and nonhazardous organics can be treated biologically, provided that the proper organism distribution can be established. This is how our authors fit in. Some will tell us how a substance that is hazardous for one group of organisms is a valuable food source for another group. It is only by viewing biological treatment systems as a dynamic population of microbes whose composition is subject to various selection pressures that proper systems can be designed, maintained, and corrected when problems arise. As a result, these chapters emphasize how fundamental principles can be used to develop commonsense approaches to establishing the desired microbial consortium, either in biological reactors designed for the treatment of heavily contaminated leachates or, in soils, using in situ and on-site decontamination techniques or, in gases, using biofilters or biotrickling filters.

Using 20 chapters, Volume I of the series, *Fundamentals and Applications,* begins with the law, the "fundamental force" that drives remediation; continues with some basic principles of mathematics that help us understand the present and predict the future; dwells on soils and the complexity that they add to the overall remediation process; fixes on the microbes and biochemical pathways that give bioremediation its uniqueness; and ends with an academic understanding of practice.

Volume II, *Bioremediation Technology Developments,* uses 20 chapters to lead us through a plethora of subjects ranging from the control of filaments, removal of phosphorus, and the treatment of chemical warfare agents in activated sludge processes to exotic biological systems, including those that use the white rot fungus, halophiles, and higher forms of plants, and fixed-film systems that treat chlorinated organics.

Volume III, *Bioremediation Technologies,* is divided into two sections: "International Bioremediation Agenda" and "Pilot-, Full-Scale, and Commercial Demonstration." In 22 chapters, this volume provides insight into how bioremediation is viewed throughout the world and gives full-scale examples of how it has been applied for the treatment of contaminated liquids, soils, and gases.

All of the chapters in this series have been peer-reviewed. To these reviewers, we owe our deepest gratitude. We would also like to thank the graduate students at the University of Notre Dame, who spent many hours helping select authors (that they would like to see in the book), editing, and organizing.

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