Environmental Microbiology and Biotechnology

Anoop Singh • Shaili Srivastava • Dheeraj Rathore • Deepak Pant Editors

# Environmental Microbiology and Biotechnology

Volume 1: Biovalorization of Solid Wastes and Wastewater Treatment



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## Foreword



Dr Hemant Purohit Dr Shekhar C. Mande

We are witnessing exhilarating times in technological shifts, wherein the resource management processes are seeking "Green options" with almost no waste generation. For any country, to address quality of life, it should have an ecosystem sustainability plan with effective resource management that can only be achieved, if it is energy-efficient, biodiversity-conscious, with no-waste attitude. Waste management is an essential step towards achieving the sustainability goals.

This biotransformation capacities of microbes and its possible exploitation have given rise to a lot of new environmental applications such as in situ bioremediation for recalcitrant pollutants like petroleum contaminants (polycyclic aromatic hydrocarbons), metal ion precipitation through transformations, energy recovery from wastewaters by designing microbial fuel cells, or electricity-driven bio-production using microbial systems. This book is targeted at a broad audience, mainly researchers, environment specialists, academicians, entrepreneurs, industrialists, policymakers, and others who wish to know the latest development and future perspectives of microbial and biotechnological approaches for greener and cleaner environment of the future and also discusses the bottlenecks of the various technologies that current status of the scale-up and commercialization.

Waste management mostly involves a series of balanced bioprocesses, which ensures resource recovery in terms of materials or energy in relatively cleaner ways. The postprocess waste inventory and its utilization at every level, from daily life, industry to ecosystem is dealt in this book. As an example, according to the World Bank's What a Waste 2.0 report, the world generates 2.01 billion tonnes of municipal solid waste annually that can be a resource through proper segregation and valorization to generate value-added products. There are also parallel documents which are suggesting utilization and valorization of wastewater and such issues are scientifically deliberated in this book.

The other issue linked with resource management is linked to the waste to energy conversion. The use of renewable energy sources has achieved a significant role in resource management, wherein bioprocesses have been designed for utilization of organic waste to biomethanation, bioethanol, and bio-hydrogen which took a lot of scientific attention in recent days and these bioprocesses have been seen as future clean energy options.

Overall the book addresses all the technical aspects related to resource management and recommends the application of microbial capacities for waste management as the only option for sustainability.

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cowards

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## Preface

Environmental microbiology and biotechnology are essential in the modern lifestyle as they are directly linked with environment, human health, economy and serve as a foundation to produce novel bio-products and energy. The main areas of utilization of these technologies for human welfare include bioremediation, waste management, waste valorization, energy production, health, hygiene, biological control, biofertilizers and natural product discovery. Environmental microbiology and biotechnology will continue to engage future generations of scientists, engineers, entrepreneurs and policymakers for the well-being of human and maintaining the natural resources.

Microorganisms are ubiquitous and inhabit soil, water, air and sediments as well as animals and plants living there. Prokaryotic microorganisms represent by far the largest reservoir of genetic diversity on Earth. They are much older than protests, metazoans and plants. They outnumber all other organisms, have a larger biomass and make the planet liveable by managing its biogeochemistry, cycling nutrients and breaking down wastes, natural or anthropogenic. Microbes possess the highest potential for the production of bioactive products, enzymes, polymers and most of the tools used in biotechnology. A diverse range of these microbes play a major role in our life and are key players in several environmental processes. Most of these are natural processes such as agriculture (nitrogen fixation), waste degradation (bioremediation, anaerobic digestion) and maintaining the natural recycling processes. This ability of microbes in transforming one substrate to another through their metabolism has given rise to a lot of new environmental applications such as in situ bioremediation for recalcitrant pollutants such as petroleum contaminants (polycyclic aromatic hydrocarbons), energy recovery from wastewaters in microbial fuel cells (MFCs) and electricity-driven bioproduction using microbial electrosynthesis. Bioremediation utilizes the application of microorganisms (bacteria, fungi, yeast and algae), to clean up contaminated sites. In this process, hazardous organic compounds are broken down, which serve as food for the microorganisms. Traditionally, the identification and characterization of microbial communities in contaminated soil and water have been limited to those microorganisms that are culturable. However, through the use of culture-independent molecular techniques, new insights into the composition of uncultivated microbial communities have been gained.

The uncultured microorganism could be exploited by the use of biotechnological tools for the benefit of environmental restoration. Biotechnology is a valuable tool which promotes and helps to regulate the biological system for efficient use of microorganism and plant. Biotechnology applications including genomics and proteomics analysis, bioinformatics, sequencing and imaging are all techniques to generate vast amounts of information, which can be utilized for the betterment of human well-being. Biotechnological applications on microbes could be more efficiently utilized for environmental protection by utilizing them for the purpose of wastewater treatment, degradation of toxic compounds, food purpose, sustainable agriculture, climate mitigation and industrial applications.

The present book is an effort to provide an up-to-date information and knowledge on the state-of-the-art applications of biotechnological and microbiological tools for the upliftment of environment by the internationally recognized experts and subject peers in different areas of biotechnology, microbiology and environment. It is a comprehensive collection of chapters related to possible applications of biotechnological and microbiological techniques in solid waste management, wastewater treatment, agriculture, energy and environmental health. The book is divided into two volumes, volume I comprises three sections, viz. Solid Waste Management, Water Treatment Technology and Agricultural Utilization and volume II comprises two sections, viz. Bioenergy and Environmental Health. An introductory chapter is also included in volume I, which gives a general background of current biotechnological and microbiological techniques available for the treatment of various waste and development of value-added products, their utilization for various purposes, socio-economic relevance of these technologies and their associated risks. Volume I covers three sections: Section I is focused on solid waste management and covers waste valorization, green polymer, management of different wastes, their industrial perspective, challenges and opportunities, etc. Section II deals with the utilization of microbial and biotechnological approaches for the management of agricultural waste, production of biofertilizers, biological pest control and future perspective of these technologies in agriculture. Section III covers the treatment of wastewater through microbial biotechnology, its electrochemistry, biotransformation of pollutants, applications and their constraints and opportunities.

New developments in the applications of biotechnical and microbiological methodology to reduce the wastage by converting them into valuable products and reducing the environmental pollution due to their disposal, from all over the world have been discussed and, wherever possible, complemented with real-life examples by the renowned experts in the field. Integration of all the recent developments into a new, consistent methodology for each type of biotechnological and microbiological system is the main aim of this book. A major advantage of this book is that it also provides advice on which procedures should be followed to achieve adequate, relevant and acceptable results. We sincerely hope that this book will contribute to the necessary transition to environmentally benign and sustainable utilization of various waste products. Though we have tried to be very objective in our choice of topics to be covered in this book, some not so common themes might have been missed out but which may become important in the future, we will try to cover them in the second edition of the book.

This book is aimed at a broad audience, mainly researchers, environment specialists, academicians, entrepreneurs, industrialists, policymakers and others who wish to know the latest development and future perspectives of microbial and biotechnological approaches for the upliftment of the environment and also discusses the bottlenecks of the various technologies that currently limit the scaleup and commercialization. This book is intended to have three roles and to serve three associated audiences, namely the students and research community who will benefit from the lucid explanation of the possible applications of biotechnology and microbiology for the betterment of environment, the policymakers who will find it easier to identify the pros and cons of biotechnological and microbiological systems for the welfare of environment and human being and finally the industries involved as it will give them a feeling about the current loopholes and ways to fix them. Each chapter begins with a fundamental explanation for general readers and ends with in-depth scientific details suitable for expert readers. The text in all the chapters is supported by numerous clear, illustrative and informative diagrams, flowcharts and comprehensive tables detailing the scientific advancements, providing an opportunity to understand the process thoroughly and meticulously. Written in a lucid style, the book comprehensively covers each point to give the reader a holistic picture about environmental microbiology and biotechnology and its future perspective. The book may even be adopted as a textbook for university courses that deal with environmental microbiology and biotechnology.

Despite the best efforts of authors and editors along with extensive checks conducted by many experts in the field of environmental microbiology and biotechnology, mistakes might have crept in inadvertently. We would appreciate if the readers could highlight these and make comments or suggestions to improve and update the book contents for future editions.

New Delhi, India Gurugram, Haryana, India Gandhinagar, Gujarat, India Mol, Belgium Anoop Singh Shaili Srivastava Dheeraj Rathore Deepak Pant

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# Contents

| 1   | <b>Perspectives of Environmental Microbiology and Biotechnology</b><br>Anoop Singh, Dheeraj Rathore, Deepak Pant, and Shaili Srivastava                        | 1   |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Par | t I Solid Waste Management                                                                                                                                     |     |
| 2   | Towards Waste Valorization: A Promising and SustainableApproach of Waste ManagementGoldy Shah, Dhruv Singh, Shivali Sahota, and Pooja Ghosh                    | 19  |
| 3   | Bioplastics: A Green Approach Toward SustainableEnvironmentPratibha Singh and Roli Verma                                                                       | 35  |
| 4   | Microbial Procession During Decomposition of Organic Wastes<br>Mohd Arshad Siddiqui and R. Hiranmai Yadav                                                      | 55  |
| 5   | <b>Electronic Waste Management: Challenges and Opportunities</b><br>Deepak Pant, Tenzin Dolker, Somvir Bajar, and Anita Singh                                  | 69  |
| 6   | Heavy Metal Pollution: An Insight Towards Its Infiltration,Impact and RemediationM. K. Ramkumar, K. Preeti, K. Varuna, Maulin P. Shah,and S. Senthil Kumar     | 91  |
| 7   | Biotransformation of Chitinous Waste into Value-AddedProductsManish Kumar, Vivekanand Vivekanand, and Nidhi Pareek                                             | 113 |
| Par | t II Agricultural Utilization                                                                                                                                  |     |
| 8   | Utilization and Management of Agricultural Wastes for Bioenergy<br>Production, Weed Control, and Soil Improvement Through<br>Microbial and Technical Processes | 143 |

| 9   | Plant Tissue Culture: Beyond Being a Tool for Genetic   Engineering   Deepak Sehgal and Tanveer Khan                                                                                   | 175 |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 10  | Microbial and Biotechnological Approaches in the Production<br>of Biofertilizer                                                                                                        | 201 |
| 11  | A Prelude of Plant Strategies to Deal with the Peril of Salinity:<br>An Archive of Regulatory Responses                                                                                | 221 |
| Par | t III Water Treatment Technology                                                                                                                                                       |     |
| 12  | Prime Techniques for Pre- and Post-Treatments of Anaerobic<br>Effluents and Solids                                                                                                     | 255 |
| 13  | Nanoscale Materials and their Potential Application in PotableWater and Wastewater TreatmentSumistha Das and Nitai Debnath                                                             | 291 |
| 14  | <b>Efficiency of Graphene-Based Forward Osmosis Membranes</b><br>Hanaa M. Hegab, Ranwen Qu, Christopher P. Saint, Linda Zou,<br>Deepak Pant, Milena Ginic-Markovic, and Ahmed ElMekawy | 309 |
| 15  | Constructed Wetland: A Green Technology for Wastewater<br>Treatment                                                                                                                    | 335 |
| Ind | ex                                                                                                                                                                                     | 365 |

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