

---

# Optimization and Applicability of Bioprocesses

---

Hemant J. Purohit • Vipin Chandra Kalia  
Atul N. Vaidya • Anshuman A. Khardenavis  
Editors

# Optimization and Applicability of Bioprocesses

 Springer

*Editors*

Hemant J. Purohit  
Environmental Biotechnology and Genomics  
Division, CSIR – National Environmental  
Engineering and Research Institute  
(CSIR-NEERI)  
Nagpur, Maharashtra, India

Vipin Chandra Kalia  
Microbial Biotechnology and Genomics  
CSIR – Institute of Genomics and Integrative  
Biology  
New Delhi, India

Atul N. Vaidya  
Solid and Hazardous Waste Management  
Division, CSIR – National Environmental  
Engineering and Research Institute  
(CSIR-NEERI)  
Nagpur, Maharashtra, India

Anshuman A. Khardenavis  
Environmental Biotechnology and Genomics  
Division, CSIR – National Environmental  
Engineering and Research Institute  
(CSIR-NEERI)  
Nagpur, Maharashtra, India

ISBN 978-981-10-6862-1      ISBN 978-981-10-6863-8 (eBook)  
<https://doi.org/10.1007/978-981-10-6863-8>

Library of Congress Control Number: 2017960179

© Springer Nature Singapore Pte Ltd. 2017, corrected publication 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature  
The registered company is Springer Nature Singapore Pte Ltd.  
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

*Dedicated to our mentors  
and  
inspiration –  
The respected Mr. Dashrath Manjhi:  
The Mountain Man*

---

## Preface

Natural resources are limited and their consumption rates are very high. A systematic approach is required for sustainable management of resources. It primarily involves integration of green innovative biotechnological strategies and ecoengineering. The issue revolves around the interaction and adaptability of plants, animals, microbes, and their adaptability in soil, air, and water. Plants need to enhance their tolerance toward hydrocarbons, petrochemical pollutants and soil salinity, temperature, and drought. These strategies are expected to enhance biomass and bioenergy production under suboptimal conditions, resulting in sustainable agriculture, forestry, protection of landscape, and biodiversity. Biological processes can be optimized by integrating bioinformatics tools, providing great perspectives to sustainable development. An integral part of the interaction of different organisms is to monitor them at a single cell level. Modern molecular techniques such as fluorescence in situ hybridization (FISH), highly sensitive catalyzed reporter deposition (CARD)-FISH, and in situ DNA-hybridization chain reaction (HCR) and methods for detecting mRNA and/or functional genes have been described. These techniques have been supplemented with metagenomics analysis, which reveals that a large proportion of microorganisms are as yet to be identified and also that they play an important and necessary role in establishing bioprocesses. In the book entitled *Optimization and Applicability of Bioprocesses*, we will be presenting the status of the diverse possibilities and the strategies for their application for human welfare. The book provides strategies for systematic approaches for sustainable management of resources and insights into integration of green innovative biotechnological strategies and ecoengineering. The well-illustrated chapters have been written by the experts in the area. It provides information on thrust scientific R&D areas for prospective researchers and graduate students. We are sincerely indebted to all the contributors, whose efforts have brought this book to fruition.

New Delhi, India

Vipin Chandra Kalia

---

# Contents

<b>1</b>	<b>Recent Advances in Optimization of Environmental Bioprocesses</b> . . . . .	<b>1</b>
	Anshuman A. Khardenavis, Atul N. Vaidya, Vipin Chandra Kalia, and Hemant J. Purohit	
<b>2</b>	<b>Visualization of Microorganisms in Bioprocesses</b> . . . . .	<b>13</b>
	Tsuyoshi Yamaguchi and Kengo Kubota	
<b>3</b>	<b>Integrated Innovative Biotechnology for Optimization of Environmental Bioprocesses and a Green Economy</b> . . . . .	<b>27</b>
	Jan W. Dobrowolski, Dawid Bedla, Tomasz Czech, Florian Gambuś, Krystyna Górecka, Waldemar Kiszczak, Tomasz Kuźniar, Robert Mazur, Agata Nowak, Małgorzata Śliwka, Obid Tursunov, Aleksandra Wagner, Jerzy Wieczorek, and Magdalena Zabochnicka-Świątek	
<b>4</b>	<b>Bioprocess for Solid Waste Management</b> . . . . .	<b>73</b>
	Radhika Deshmukh, Anshuman A. Khardenavis, and Hemant J. Purohit	
<b>5</b>	<b>Processes of Microbial Transformation and Physical Removal of Polychlorinated Biphenyls (PCBs) in Wastewater Treatment</b> . . . . .	<b>101</b>
	Soliver C. Fusi, Alisha Y. Chan, and Birthe V. Kjellerup	
<b>6</b>	<b>Sequestration Options for Phosphorus in Wastewater</b> . . . . .	<b>115</b>
	Varsha Jha, Sampada Puranik (Chande), and Hemant J. Purohit	
<b>7</b>	<b>Bioremediation of Terrestrial Oil Spills: Feasibility Assessment</b> . . . . .	<b>141</b>
	Pradnya Nagkirti, Azhar Shaikh, Gowdaman Vasudevan, Vasundhara Paliwal, and Prashant Dhakephalkar	
<b>8</b>	<b>Role of Clostridial Nitroreductases in Bioremediation</b> . . . . .	<b>175</b>
	Razia Kutty and George N. Bennett	
<b>9</b>	<b>Activated Sludge Process and Energy</b> . . . . .	<b>187</b>
	J. Rajesh Banu, U. Ushani, and R. Yukesh Kannah	

<b>10</b>	<b>Mass Production of Microalgae in Photobioreactors for Biodiesel Application: Selection, Limitations, and Optimization</b> . . . . .	211
	Sanjay Pawar and Suvidha Gupta	
<b>11</b>	<b>Biofloculants and Production of Microalgal Biomass</b> . . . . .	233
	Mihir C. Sarang and Anuradha S. Nerurkar	
<b>12</b>	<b>Biohydrogen Production: An Outlook of Fermentative Processes and Integration Strategies</b> . . . . .	249
	G.N. Nikhil, Omprakash Sarkar, and S. Venkata Mohan	
<b>13</b>	<b>Development of Dry Anaerobic Technologies of Bio-waste and Unlock the Barriers for Valorization</b> . . . . .	267
	Ahmed Tawfik and Mohamed Elsamadony	
<b>14</b>	<b>Modelling for Anaerobic Process</b> . . . . .	283
	J. Rajesh Banu, S. Kavitha, and K. Tamilarasan	
<b>15</b>	<b>Biofilm Microenvironments: Modeling Approach</b> . . . . .	305
	Saheli Ghosh, Asifa Qureshi, and Hemant J. Purohit	
<b>16</b>	<b>Microbial CO<sub>2</sub> Fixation Bioprocesses and Desert as Future Carbon Sink</b> . . . . .	325
	Leena Agarwal, Nishant A. Dafale, and Hemant J. Purohit	
<b>17</b>	<b>Bioprocess Network for Solid Waste Management</b> . . . . .	349
	Federico Micolucci, Marco Gottardo, and Wanderli Rogério Moreira Leite	
<b>18</b>	<b>The Application of Computer Image Analysis in Water Toxicity Tests</b> . . . . .	383
	Piotr Lewicki, Robert Mazur, and Dawid Bedla	
<b>19</b>	<b>Mining the Microbial Community for Redefining the Bioprocesses in the Future</b> . . . . .	409
	Hemant J. Purohit, Anshuman A. Khardenavis, Atul N. Vaidya, and Vipin Chandra Kalia	
	<b>Correction to: Integrated Innovative Biotechnology for Optimization of Environmental Bioprocesses and a Green Economy</b> . . . .	C1
	<b>Correction to: Bioprocess for Solid Waste Management</b> . . . . .	C3

---

## About the Editors

**Hemant J. Purohit** is head of the Environmental Biotechnology and Genomics Division, CSIR-National Environmental Engineering and Research Institute, Nagpur. He completed his Ph.D. at Nagpur University in 1986 with support from CSIR Research Fellowships (JRF and SRF). He has training in microbial biochemistry from the Department of Biochemistry, University of Hull, UK (Commonwealth Fellowship), and also from the Laboratory of Molecular Biology, NINDS, NIH, Bethesda (Fogarty International Exchange Program Fellowship). He also developed the environmental genomics program at CSIR-NEERI. His key area of interest is decision-making by the bacterial/microbial community. He has been involved in designing a strategy for capturing microbial diversity by interfacing culturable and DNA fingerprinting tools; developing genomics-based monitoring tools for EIA and bioremediation processes; studying stress-dependent microbial response using dynamic gene expression and its application in bioprocess optimization; and developing insights into microbial capacities for utilization of organics through genome sequence analysis, etc. He has been project coordinator for a number of high-value projects and has 225 publications to his credit. Dr. Purohit is an associate editor of *Applied Biochemistry and Biotechnology* and editor of the *Indian Journal of Microbiology* and *PLoS One*.

**Vipin Chandra Kalia** is an emeritus scientist and ex-chief scientist at Microbial Biotechnology and Genomics, CSIR-Institute of Genomics and Integrative Biology, Delhi. He obtained his M.Sc. and Ph.D. degrees in genetics from the Indian Agricultural Research Institute, New Delhi. He has been elected as fellows of (1) the Association of Microbiologists of India (AMI), (2) the National Academy of Sciences (NASc), and (3) the National Academy of Agricultural Sciences (NAAS). His main areas of research are microbial biodiversity, genomics and evolution, bioenergy, biopolymers, antimicrobials, quorum sensing, and quorum quenching. He has published over 100 papers in scientific journals such as (1) *Nature Biotechnology*, (2) *Biotechnology Advances*, (3) *Trends in Biotechnology*, (4) *Critical Reviews in Microbiology*, (5) *Bioresource Technology*, (6) the *International Journal of Hydrogen Energy*, (7) *PLoS ONE*, (8) *BMC Genomics*, (9) *Gene*, and (10) the *Annual Review of Microbiology*. He has an h index of 32 and an i10 index of 71. He has edited three books: *Quorum Sensing Vs Quorum Quenching: A Battle with No*

*End in Sight* (2015, Springer India) and *Microbial Factories* Vol 1 and 2 (2015). He is currently the editor in chief of the *Indian Journal of Microbiology* and editor of (1) *PLoS ONE*, (2) the *Journal of Microbiology and Biotechnology* (Korea), (3) *Applied Biochemistry and Biotechnology* (USA), (4) *International Scholarly Research Notices* (Energy), (5) *Dataset Papers in Science* (Microbiology), and (6) the *Journal of Molecular and Genetic Medicine*. He is a life member of the following scientific societies: (1) the Society of Biological Chemists of India; (2) the Society for Plant Biochemistry and Biotechnology, India; (3) the Association of Microbiologists of India; (4) the Indian Science Congress Association; (5) the Bioenergy Society of India; and (6) the Biotech Research Society of India (BRSI). He is also a member of the American Society for Microbiology.

**Atul N. Vaidya** is head of the Solid and Hazardous Waste Management Division, National Environmental Engineering Research Institute (CSIR), Nagpur. He is also a professor at AcSIR (Academy of Scientific and Innovative Research), New Delhi. Since completing his Ph.D. at Nagpur University in 2001, he has been involved in developing strategies for managing municipal solid waste through sustainable methods, the application of biotechnological processes and cleaner technologies for treating industrial wastewaters, and the restoration of the environment through recovery of value-added products such as biogas from the organic fraction of municipal solid waste. He has been a project leader in a number of high-value projects and has 63 publications to his credit. He is a member of the scientific advisory panels of several national and international committees and has been recognized for his work as member of the Expert Committee for Proper MSW Management at Srinagar, Jammu and Kashmir, by the National Green Tribunal.

**Anshuman A. Khardenavis** is a senior scientist at the Environmental Biotechnology and Genomics Division, National Environmental Engineering Research Institute (CSIR), Nagpur. He is also an asst. professor at AcSIR (Academy of Scientific and Innovative Research), New Delhi. He completed his Ph.D. at Nagpur University in 2011 and has been involved in developing methods and strategies for the recovery of value-added products from organic solid waste, such as keratinases from feather waste, and polyhydroxyalkanoates (PHAs) from activated sludge biomass; the design and operation of reactors for managing organic waste through biomethanation; studying the role of substrate-specific microbial community plasticity in the efficiency of anaerobic digestion; and the evaluation of microbial capacities for the utilization of organics through genome sequence analysis. He has been a project leader in a number of high-value projects sponsored by government agencies and industries. He has 24 publications to his credit. He has received a number of prestigious awards, including a Lien Environmental Fellowship, Singapore, and CSIR-UGC Research Fellowships (JRF and SRF).