

Naveen Kumar Arora • Jitendra Mishra
Editors

Biotechnological Solutions for a Sustainable Future

From Soil Health to Industrial Applications

 Springer

Editors

Naveen Kumar Arora
Department of Environment Science
Babasaheb Bhimrao Ambedkar University
Lucknow, Uttar Pradesh, India

Jitendra Mishra
Amity School of Biological Sciences
Amity University Punjab
Mohali, Punjab, India

ISSN 2512-1901

ISSN 2512-1898 (electronic)

Microorganisms for Sustainability

ISBN 978-981-95-3988-8

ISBN 978-981-95-3989-5 (eBook)

<https://doi.org/10.1007/978-981-95-3989-5>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2026

This work is subject to copyright. All rights are solely and exclusively licensed 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, expressed 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.

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

If disposing of this product, please recycle the paper.

Preface

In an era of converging environmental crises—accelerating climate change, unprecedented resource depletion, and widespread pollution—humanity faces a defining moment. *Biotechnological Solutions for a Sustainable Future: From Soil Health to Industrial Applications* delivers both a roadmap and a call to action. This volume unites multidisciplinary expertise to address a singular imperative: *employing biological systems to restore planetary health while advancing human well-being*.

Part I: Soil Health and Resource Valorization

We begin at the root of sustainability—healthy soils. Chapter 1 unveils *biochar-based fertilizers* as carbon-negative tools that reverse land degradation while sequestering atmospheric CO₂. Chapter 2 transforms waste into valuable resources, converting agricultural and industrial residues into *next-generation biofuels* for circular economies. Chapter 3 pioneers the conversion of food waste into *high-performance biodegradable packaging*—simultaneously displacing petroleum plastics and valorizing organic waste streams.

Part II: Environmental Remediation and Cultural Restoration

Biological systems serve as our most precise tools for environmental detoxification. Chapter 4 deploys microbial consortia against persistent pollutants, while Chap. 5 showcases *CRISPR-engineered plastic-degrading microbes*, *mycoremediation* of oil spills, and *hyperaccumulator plants* for heavy metals—proving nature’s superiority over conventional cleanup methods.

Moving beyond basic remediation, Chap. 6 harnesses *microbial biosurfactants* to emulsify hydrocarbons and chelate metals, while Chap. 7 applies *microbial nanotechnology* for sustainable wastewater treatment. Chapter 8 reimagines radioactive waste management through integrated biological and physicochemical approaches, and Chap. 9 pioneers *enzymatic restoration of cultural heritage*—safeguarding both ecological systems and human history.

Part III: Industrial Applications for Food Safety and Human Health

Life sciences transcend the research bench to transform industries. Chapter 10 engineers *nanoparticle-enhanced antimicrobial packaging* that extends food shelf-life

while ensuring consumer safety. Chapter 11 exposes the carcinogenic threat of *fumonisin*s and charts mitigation pathways across food production chains. Chapter 12 unlocks *microbial carotenoids* as sustainable pigments for nutraceuticals, pharmaceuticals, and industrial applications—replacing synthetic alternatives while delivering enhanced health benefits.

Scalability gaps, economic viability, and regulatory frameworks demand urgent cross-disciplinary collaboration. Yet these obstacles ignite innovation—driving optimized bioreactor designs, risk-assessed engineered microorganisms, and policy-ready life cycle assessment (LCA) models. The evidence is unequivocal: biological solutions are environmentally essential, economically viable, and industrially scalable.

We extend profound gratitude to the pioneering researchers whose work fills these pages. Together, they demonstrate how biotechnology harmonizes *ecological resilience*, *economic prosperity*, and *social equity*.

This volume represents more than a scientific compilation—it stands as a testament to biotechnology’s power to build a future where healthy soils and thriving industries coexist. Within these pages lies the blueprint for a truly sustainable planet.

Lucknow, Uttar Pradesh, India
Mohali, Punjab, India

Naveen Kumar Arora
Jitendra Mishra

Contents

Part I Soil Health and Resource Valorization

- 1 Biochar-Based Fertilizers: A New Approach to Sustainable Soil Management. 3**
Durdigul Botirova, Shoxnoza Zakirova, Muxlisa Soipova,
and Dilfuza Egamberdieva
- 2 Bioconversion of Agricultural/Industrial Waste into Biofuels 19**
Hamza Umar, Kanchan Bhatt, Aharnish Maurya, and Ashish
- 3 Sustainable Biodegradable Packaging Materials
from Food Waste 47**
Neela Satheesh, Aparna Mahajan, and Eskindir E. Tadesse

Part II Environmental Remediation and Cultural Restoration

- 4 Microbes and Bioremediation: An Emerging Approach
for Environmental Cleanness. 87**
Simpal Kumari and Atul Kumar Srivastava
- 5 Beyond Conventional Cleanup: The Transformative
Potential of Advanced Bioremediation 115**
V. I. Gwa, E. J. Ekefan, and F. A. Lum
- 6 Microbial Biosurfactants and Their Role in Pollutant Cleanup. 139**
Manpreet Kaur and Reena Gupta
- 7 Microbial Nano-biotechnology for Wastewater Research:
A Sustainable Approach. 167**
Neha Agarwal, Shachi Mishra, Vijendra Singh Solanki,
and Sankara Rao Muditana

- 8 Advancing Radwaste Remediation: Innovations, Strategies, and Future Perspectives 187**
Sachchit Patel, Yogita Pandey, Siddraj Thakur, Hitanshu Kapadiya,
Ronakkumar Bhadaniya, and Arpit Shukla
- 9 Applied Biotechnology in the Restoration of Cultural Heritage 207**
Mamta Kodarkar and Srikanth Mutnuri

Part III Industrial Applications for Food Safety and Human Health

- 10 Cutting-Edge Antimicrobials in Food Packaging Applications 225**
Neetu Singh, Alka Nanda, Ayushi Singh, Puja Kumari,
and Tanya Singh
- 11 The Silent Menace of Fumonisin: Cancer Risks, Outbreak Lessons, and Mitigation Pathways 255**
Livpreet Kaur, Gurleen Kaur, Shiv Kumar Dwivedi,
and Jitendra Mishra
- 12 Microbial Carotenoids: Biosynthesis Pathways, Production Strategies, and Their Industrial Applications 279**
Rashmi Shahi, N. Lohith Kumar, and Ankita Mishra

Bioconversion of Agricultural/Industrial Waste into Biofuels

| Chapter | First Online: 02 January 2026

| pp 19–46 | [Cite this chapter](#)



Biotechnological Solutions for a Sustainable Future

Hamza Umar, Kanchan Bhatt, Aharnish Maurya & Ashish

Part of the book series: [Microorganisms for Sustainability](#) ((MICRO,volume 55))

140 Accesses

Abstract

Rising demand for renewable energy has increased interest in biofuels as sustainable alternatives to fossil fuels. This chapter examines the bioconversion of agricultural and industrial waste into first- and second-generation biofuels, addressing waste valorization, energy security, and environmental sustainability. The study explores lignocellulosic biomass and agricultural residues as feedstocks, utilizing both biochemical and thermochemical conversion pathways, including fermentation, anaerobic digestion, and pyrolysis. Key focus areas include microbial consortia optimization, engineered strains, and advanced bioreactor design to enhance biofuel yields. The chapter evaluates environmental benefits, economic feasibility, and policy frameworks for widespread adoption. Life cycle

assessment (LCA) demonstrates long-term sustainability through carbon footprint reduction and integration with existing industrial systems. This waste-to-biofuel approach promotes a circular bioeconomy, reduces waste disposal challenges, and aligns global climate action goals through multidisciplinary strategies.

 This is a preview of subscription content, [log in via an institution](#)  to check access.

Access this chapter

Log in via an institution

Subscribe and save

✓ Springer+

from €37.37 /Month

Starting from 10 chapters or articles per month

Access and download chapters and articles from more than 300k books and 2,500 journals

Cancel anytime

View plans →

Buy Now

^ Chapter

EUR 29.95

Price includes VAT (India)

Available as PDF

Read on any device

Instant download

Own it forever