



CRC Press
Taylor & Francis Group

GREEN CHEMICAL INNOVATIONS
AND SUSTAINABILITY SERIES



MICROBIAL GREEN SURFACTANTS ENVIRONMENTAL SUSTAINABILITY AND ECOLOGICAL REMEDIATION

Ibrahim Yahia Yaagoob, Jeenat Aslam,
Shikha Dubey, and
Chandrabhan Verma

Microbial Green Surfactants

This volume in the Green Chemical Innovations and Sustainability Series presents the latest research on biosurfactant molecules and their role in environmental sustainability. Advances in organic chemistry have traditionally enabled the development of hydrophobic and hydrophilic surfactants, largely relying on synthetic materials such as organic polymers. In contrast, biosurfactants—derived from microorganisms or plant sources—offer significant advantages, including high biodegradability, low toxicity, ready availability of raw materials, and ease of application. Also known as green surfactants, these sustainable alternatives play a vital role in modern industrial sectors, including petroleum recovery, personal care products, food processing, and medical applications.

- Provides chronological advancements in microbial green surfactants using smart bio-based microorganisms or plant materials.
- Discusses how green surfactants are obtained from sources based on petroleum or those with microbial or botanical origins and have been extensively used for environmental applications.
- Includes current developments and challenges during manufacturing of green surfactants.
- Up-to-date reference material, including websites of interest and information about the latest research.

Green Chemical Innovations and Sustainability

Series Editor, Professor Anja Mudring, *Aarhus University, Denmark*

This series is dedicated to bringing together academic researchers, industry professionals, teachers, law and policy makers, who constitute the growing green chemistry community. We welcome volumes on recent innovations, as well as accompanying educational resources from those working in related disciplines across chemistry, chemical engineering, and environmental science.

All contributions should clearly demonstrate impact to advancing the field and where possible reference the 12 Principles of Green Chemistry and the Sustainable Development Goals agreed by the United Nations in 2015. Volumes could cover:

- Green synthesis and catalysis
- Green manufacturing and engineering
- Green product design
- Green chemistry education
- Critical raw materials and sustainable resources
- Energy harvest, storage, and savings
- Circular economy
- Environmental chemistry and green metrics
- Ethics, legislation, and economics

Recent Advances in Activated Carbon: Synthesis, Properties and Applications

Ho Soon Min, Heri Septya Kusuma, and Yogesh Chandra Sharma

Perfluoroalkyl and Polyfluoroalkyl Substances: Environmental Fate, Health Impacts, and Remediation Strategies

Mohamed Aly Hassaan, Kingsley Eghonghon Ukhurebor, Uyiosa Osagie Aigbe, Robert Birundu Onyancha, Amr Gamal Dardeer, Marwa Ramadan ElKatory, Kenneth Atoe, Ahmed El Nemr

Microbial Green Surfactants: Environmental Sustainability and Ecological Remediation

Ibrahim Yahia Yaagoob, Jeenat Aslam, Shikha Dubey, and Chandrabhan Verma

Microbial Green Surfactants

Environmental Sustainability and Ecological Remediation

Edited by
Ibrahim Yahia Yaagoob, Jeenat Aslam,
Shikha Dubey, and Chandrabhan Verma



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

Designed cover image: Shutterstock

First edition published 2026

by CRC Press

2385 NW Executive Center Drive, Suite 320, Boca Raton FL 33431

and by CRC Press

4 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

CRC Press is an imprint of Taylor & Francis Group, LLC

© 2026 Ibrahim Yahia Yaagoob, Jeenat Aslam, Shikha Dubey, and Chandrabhan Verma

Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, access www.copyright.com or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. For works that are not available on CCC please contact mpkbookspermissions@tandf.co.uk

For Product Safety Concerns and Information please contact our EU representative GPSR@taylorandfrancis.com. Taylor & Francis Verlag GmbH, Kaufingerstraße 24, 80331 München, Germany.

Trademark notice: Product or corporate names may be trademarks or registered trademarks and are used only for identification and explanation without intent to infringe.

ISBN: 978-1-032-89088-3 (hbk)

ISBN: 978-1-032-89162-0 (pbk)

ISBN: 978-1-003-54151-6 (ebk)

DOI: 10.1201/9781003541516

Typeset in Times

by SPi Technologies India Pvt Ltd (Straive)

Contents

Preface.....	viii
About the Editors	x
Contributors	xii

PART I Surfactants and Green Surfactants: Fundamental, Properties, Processing, and Classifications

Chapter 1	Green Surfactants: Fundamentals, Classification, General Properties, and Functions	3
	<i>Gaydaa Al Zohbi and Anwar Hamade</i>	
Chapter 2	Marine Microorganisms-Based Green Surfactants: Fundamental, Sources, Processing, Production, and Purification	44
	<i>Loubna El Joumri, Youssra El Hamdouni, Najoua Labjar, Hamid Nasrellah, Ayoub Cherrat, Houda Labjar, Ghita Amine Benabdallah, Mohamed Dalimi, and Souad El Hajjaji</i>	
Chapter 3	Microorganism-Based Green Surfactant: Clean and Green Solutions (Biodegradability, Low-toxicity, Biocompatibility, and Environmental Benefits)	58
	<i>Rahul Kumar Vishwakarma, Stuti Gupta, Anushka Pallavi, Kundan Kumar, and Ajay Kumar Tripathi</i>	
Chapter 4	Toxicity Measurements of Surfactants: Biototoxicity, Biodegradability, and Bioaccumulation	82
	<i>Lakhloufi Soraya, Youssra El Hamdouni, Najoua Labjar, Hamid Nasrellah, Ayoub Cherrat, Houda Labjar, and Souad El Hajjaji</i>	

PART II Microorganisms-Based Green Surfactants: Industrial Applications

- Chapter 5** Green Surfactants for Heavy Metals Removal Applications 117
Vidusha Singh and Narendra Pratap Singh
- Chapter 6** Green Surfactants for Agricultural Applications 147
*Loubna El Joumri, Najoua Labjar, Abdelmjid Zouahri, Hamid
 Nasrellah, Houda Labjar, Ghita Amine Benabdallah, Mohamed
 Dalimi, and Souad El Hajjaji*
- Chapter 7** Green Surfactants for Food and Food Processing Applications 160
S. Noyel Victoria, Rabiya Sani, and R. Manivannan
- Chapter 8** Green Surfactants for Petroleum and Petrochemical
 Applications 177
*Sheerin Masroor, Omar Dagdag, Ajay Kumar, and Mohammad
 Ehtisham Khan*
- Chapter 9** Green Surfactants for Wastewater Treatment Applications:
 Mechanisms, Materials, and Environmental Impact 191
Mansi Y. Chaudhary, Shramila Yadav, and Bhaskaran
- Chapter 10** Green Surfactants for Personal Care and Cosmetics
 Applications 210
*Shveta Sharma, Humira Assad, Richika Ganjoo,
 and Ashish Kumar*

PART III Microorganisms-Based Green Surfactants: Biological Applications

- Chapter 11** Green Surfactants for Food Processing and Biological
 Applications 235
Disha Sharma and Shivani Uniyal
- Chapter 12** Green Surfactants for Biomedical Applications 245
Behrouz Seyfinejad and Elaheh Rahimpour

Chapter 13 Green Surfactants for Bioremediation Applications 268

*Abhinay Thakur, Elyor Berdimurodov, Valentine Chikaodili
Anadebe, Savas Kaya, and Abdelkader Zarrouk*

Chapter 14 Eco-Friendly Surfactants for Biowaste Decomposition:
Mechanisms and Applications..... 289

*Chan Basha Nusrath Unnisa, Arumugam Revathi,
Dhakshinamoorthy Sudha, and Kaliannan Kalaivani*

Chapter 15 Green Surfactants for Insoluble Antibiotic Applications 317

Vivek Mishra, Nisha Yadav, and Apoorva Singh

**PART IV *Microorganisms-Based Green
Surfactants: Emerging Trends*****Chapter 16** Green Surfactants and Nanomaterial Composites: Advanced
Materials for Improved Applications..... 341

Sudheer, Farhat A. Ansari, Afifa, and Rizwa

Chapter 17 Bio-Based Surfactants from Vegetable Oils for Enhanced Oil
Recovery: A Sustainable Approach 363

Vartika Verma, Tanmay Akash, and Nilanjan Pal

Chapter 18 Microbial Green Surfactants: Environmental Sustainability and
Ecological Remediation 388

*Rajendran Geetha, Jagadeesan Aravind Kumar,
Veeramalli Naveen Sahith, and Vasamsetti Saisruthi*

Index..... 410



CRC Press
Taylor & Francis Group

GREEN CHEMICAL INNOVATIONS
AND SUSTAINABILITY SERIES



MICROBIAL GREEN SURFACTANTS ENVIRONMENTAL SUSTAINABILITY AND ECOLOGICAL REMEDIATION

Ibrahim Yahia Yaagoob, Jeenat Aslam,
Shikha Dubey, and
Chandrabhan Verma

Microbial Green Surfactants

This volume in the Green Chemical Innovations and Sustainability Series presents the latest research on biosurfactant molecules and their role in environmental sustainability. Advances in organic chemistry have traditionally enabled the development of hydrophobic and hydrophilic surfactants, largely relying on synthetic materials such as organic polymers. In contrast, biosurfactants—derived from microorganisms or plant sources—offer significant advantages, including high biodegradability, low toxicity, ready availability of raw materials, and ease of application. Also known as green surfactants, these sustainable alternatives play a vital role in modern industrial sectors, including petroleum recovery, personal care products, food processing, and medical applications.

- Provides chronological advancements in microbial green surfactants using smart bio-based microorganisms or plant materials.
- Discusses how green surfactants are obtained from sources based on petroleum or those with microbial or botanical origins and have been extensively used for environmental applications.
- Includes current developments and challenges during manufacturing of green surfactants.
- Up-to-date reference material, including websites of interest and information about the latest research.

Green Chemical Innovations and Sustainability

Series Editor, Professor Anja Mudring, *Aarhus University, Denmark*

This series is dedicated to bringing together academic researchers, industry professionals, teachers, law and policy makers, who constitute the growing green chemistry community. We welcome volumes on recent innovations, as well as accompanying educational resources from those working in related disciplines across chemistry, chemical engineering, and environmental science.

All contributions should clearly demonstrate impact to advancing the field and where possible reference the 12 Principles of Green Chemistry and the Sustainable Development Goals agreed by the United Nations in 2015. Volumes could cover:

- Green synthesis and catalysis
- Green manufacturing and engineering
- Green product design
- Green chemistry education
- Critical raw materials and sustainable resources
- Energy harvest, storage, and savings
- Circular economy
- Environmental chemistry and green metrics
- Ethics, legislation, and economics

Recent Advances in Activated Carbon: Synthesis, Properties and Applications

Ho Soon Min, Heri Septya Kusuma, and Yogesh Chandra Sharma

Perfluoroalkyl and Polyfluoroalkyl Substances: Environmental Fate, Health Impacts, and Remediation Strategies

Mohamed Aly Hassaan, Kingsley Eghonghon Ukhurebor, Uyiosa Osagie Aigbe, Robert Birundu Onyancha, Amr Gamal Dardeer, Marwa Ramadan ElKatory, Kenneth Atoe, Ahmed El Nemr

Microbial Green Surfactants: Environmental Sustainability and Ecological Remediation

Ibrahim Yahia Yaagoob, Jeenat Aslam, Shikha Dubey, and Chandrabhan Verma

Microbial Green Surfactants

Environmental Sustainability and Ecological Remediation

Edited by
Ibrahim Yahia Yaagoob, Jeenat Aslam,
Shikha Dubey, and Chandrabhan Verma



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

Designed cover image: Shutterstock

First edition published 2026

by CRC Press

2385 NW Executive Center Drive, Suite 320, Boca Raton FL 33431

and by CRC Press

4 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

CRC Press is an imprint of Taylor & Francis Group, LLC

© 2026 Ibrahim Yahia Yaagoob, Jeenat Aslam, Shikha Dubey, and Chandrabhan Verma

Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, access www.copyright.com or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. For works that are not available on CCC please contact mpkbookspermissions@tandf.co.uk

For Product Safety Concerns and Information please contact our EU representative GPSR@taylorandfrancis.com. Taylor & Francis Verlag GmbH, Kaufingerstraße 24, 80331 München, Germany.

Trademark notice: Product or corporate names may be trademarks or registered trademarks and are used only for identification and explanation without intent to infringe.

ISBN: 978-1-032-89088-3 (hbk)

ISBN: 978-1-032-89162-0 (pbk)

ISBN: 978-1-003-54151-6 (ebk)

DOI: 10.1201/9781003541516

Typeset in Times

by SPi Technologies India Pvt Ltd (Straive)

Contents

Preface.....	viii
About the Editors	x
Contributors	xii

PART I Surfactants and Green Surfactants: Fundamental, Properties, Processing, and Classifications

Chapter 1	Green Surfactants: Fundamentals, Classification, General Properties, and Functions	3
	<i>Gaydaa Al Zohbi and Anwar Hamade</i>	
Chapter 2	Marine Microorganisms-Based Green Surfactants: Fundamental, Sources, Processing, Production, and Purification	44
	<i>Loubna El Joumri, Youssra El Hamdouni, Najoua Labjar, Hamid Nasrellah, Ayoub Cherrat, Houda Labjar, Ghita Amine Benabdallah, Mohamed Dalimi, and Souad El Hajjaji</i>	
Chapter 3	Microorganism-Based Green Surfactant: Clean and Green Solutions (Biodegradability, Low-toxicity, Biocompatibility, and Environmental Benefits)	58
	<i>Rahul Kumar Vishwakarma, Stuti Gupta, Anushka Pallavi, Kundan Kumar, and Ajay Kumar Tripathi</i>	
Chapter 4	Toxicity Measurements of Surfactants: Biototoxicity, Biodegradability, and Bioaccumulation	82
	<i>Lakhloufi Soraya, Youssra El Hamdouni, Najoua Labjar, Hamid Nasrellah, Ayoub Cherrat, Houda Labjar, and Souad El Hajjaji</i>	

PART II Microorganisms-Based Green Surfactants: Industrial Applications

- Chapter 5** Green Surfactants for Heavy Metals Removal Applications 117
Vidusha Singh and Narendra Pratap Singh
- Chapter 6** Green Surfactants for Agricultural Applications 147
*Loubna El Joumri, Najoua Labjar, Abdelmjid Zouahri, Hamid
 Nasrellah, Houda Labjar, Ghita Amine Benabdallah, Mohamed
 Dalimi, and Souad El Hajjaji*
- Chapter 7** Green Surfactants for Food and Food Processing Applications 160
S. Noyel Victoria, Rabiya Sani, and R. Manivannan
- Chapter 8** Green Surfactants for Petroleum and Petrochemical
 Applications 177
*Sheerin Masroor, Omar Dagdag, Ajay Kumar, and Mohammad
 Ehtisham Khan*
- Chapter 9** Green Surfactants for Wastewater Treatment Applications:
 Mechanisms, Materials, and Environmental Impact 191
Mansi Y. Chaudhary, Shramila Yadav, and Bhaskaran
- Chapter 10** Green Surfactants for Personal Care and Cosmetics
 Applications 210
*Shveta Sharma, Humira Assad, Richika Ganjoo,
 and Ashish Kumar*

PART III Microorganisms-Based Green Surfactants: Biological Applications

- Chapter 11** Green Surfactants for Food Processing and Biological
 Applications 235
Disha Sharma and Shivani Uniyal
- Chapter 12** Green Surfactants for Biomedical Applications 245
Behrouz Seyfinejad and Elaheh Rahimpour

Chapter 13 Green Surfactants for Bioremediation Applications 268

*Abhinay Thakur, Elyor Berdimurodov, Valentine Chikaodili
Anadebe, Savas Kaya, and Abdelkader Zarrouk*

Chapter 14 Eco-Friendly Surfactants for Biowaste Decomposition:
Mechanisms and Applications..... 289

*Chan Basha Nusrath Unnisa, Arumugam Revathi,
Dhakshinamoorthy Sudha, and Kaliannan Kalaivani*

Chapter 15 Green Surfactants for Insoluble Antibiotic Applications 317

Vivek Mishra, Nisha Yadav, and Apoorva Singh

**PART IV *Microorganisms-Based Green
Surfactants: Emerging Trends*****Chapter 16** Green Surfactants and Nanomaterial Composites: Advanced
Materials for Improved Applications..... 341

Sudheer, Farhat A. Ansari, Afifa, and Rizwa

Chapter 17 Bio-Based Surfactants from Vegetable Oils for Enhanced Oil
Recovery: A Sustainable Approach 363

Vartika Verma, Tanmay Akash, and Nilanjan Pal

Chapter 18 Microbial Green Surfactants: Environmental Sustainability and
Ecological Remediation 388

*Rajendran Geetha, Jagadeesan Aravind Kumar,
Veeramalli Naveen Sahith, and Vasamsetti Saisruthi*

Index..... 410