

Navnath T. Hatvate · Ajinkya Madan Satdive · Hemantkumar N. Akolkar · A. K. Haghi

Plastic Waste Management

Solutions for Sustainable Development



Synthesis Lectures on Sustainable Development

Series Editor

Thomas Siller, Civil and Environmental Engineering, Colorado State University, Fort Collins, USA

This series publishes short books related to sustainable development practices relevant to engineers, technologists, managers, educators, and policy makers. The books are organized around the United Nations Sustainable Development Goals for 2015–2030. Design for sustainability along with the economics of sustainable development will be the common themes for each book. Topics to be covered will span all the major engineering disciplines along with the natural and environmental sciences that contribute to an understanding of sustainable development. The goal of this series is to make theory and research accessible to practitioners working on sustainable development efforts.

Navnath T. Hatvate · Ajinkya Madan Satdive · Hemantkumar N. Akolkar · A. K. Haghi

Plastic Waste Management

Solutions for Sustainable Development



Navnath T. Hatvate Institute of Chemical Technology, Mumbai, Marathwada Campus Jalna, Maharashtra, India

Hemantkumar N. Akolkar Department of Chemistry Rayat Shikshan Sanstha's Abasaheb Marathe Arts and New Commerce Science College Rajapur, Maharashtra, India Ajinkya Madan Satdive Institute of Chemical Technology, Mumbai, Marathwada Campus Jalna, Maharashtra, India

A. K. Haghi Department of Chemistry Institute of Molecular Sciences University of Coimbra Coimbra, Portugal

ISSN 2637-7675 ISSN 2637-7691 (electronic) Synthesis Lectures on Sustainable Development ISBN 978-3-031-96659-0 ISBN 978-3-031-96660-6 (eBook) https://doi.org/10.1007/978-3-031-96660-6

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 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 Switzerland AG The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

If disposing of this product, please recycle the paper.

Preface

A new global catastrophe has emerged as a result of the accumulation of trash made of plastic. Plastic pollution's effects on ecosystems, human health, and the economy are urgent issues that demand quick attention and coordinated action. With the title *Plastic Waste Management—Solutions for Sustainable Development*, this book seeks to give readers a thorough understanding of the problem of plastic waste management, its effects on the environment and human health, and possible solutions for a sustainable future.

From the varieties of plastic materials and their degradation patterns to the effects of plastic pollution on the environment and human health, the book's four chapters examine the challenges of managing plastic trash. The chapters also look at current methods for managing plastic garbage, stressing their shortcomings and difficulties, and talk about fresh ideas and different strategies for doing so.

Researchers, legislators, business leaders, and anybody else interested in comprehending the problem of plastic waste management and investigating options for a sustainable future are the target audience for this book. It is our aim that this book will add to the current conversation on plastic pollution and motivate action to lessen its effects.

In addition to inspiring fresh concepts and inventions to advance a more sustainable future, we believe that this book will prove to be an invaluable tool for everyone attempting to comprehend and tackle the problem of plastic waste management.

Jalna, India Jalna, India Rajapur, India Coimbra, Portugal Navnath T. Hatvate Ajinkya Madan Satdive Hemantkumar N. Akolkar A. K. Haghi

Contents

1	Intr	oductio	n	1	
	1.1	Plastic	s and the Environmental Hazards	1	
		1.1.1	Impact of Plastics on Land	1	
		1.1.2	Impact of Plastics on Aquatic Life	2	
		1.1.3	Impact of Plastic on Air Pollution	4	
		1.1.4	Impact of Plastic on Water Pollution	4	
	1.2	Plastic	s, the Environment and Human Health	5	
		1.2.1	Bisphenol-A (BPA)	6	
		1.2.2	Phthalates	9	
		1.2.3	Polychlorinated Biphenyls (PCBs)	9	
		1.2.4	Halogenated Flame Retardants	10	
		1.2.5	Emissions from Plastic Combustion	11	
	1.3	Plastic	Waste Pollution and Sustainable Solutions	12	
		1.3.1	Reduction and Prevention Strategies	13	
	1.4	Plastic	Waste Management Strategies in Practice	16	
		1.4.1	Reduction and Prevention Strategies	17	
		1.4.2	Collection and Sorting Strategies	18	
		1.4.3	Recycling and Reuse Strategies	18	
		1.4.4	Waste-To-Energy Technologies	19	
	1.5	Conclu	asion	20	
	Refe	rences		20	
2	Cur	rent So	lutions for Sustainable Ecosystems	31	
	2.1	2.1 Introduction			
	2.2	Major	Challenges to Sustainable Ecosystems	31	
		2.2.1	Pollution	31	
		2.2.2	Climate Change and Global Warming	32	
		2.2.3	Land Degradation and Agricultural Constraints	33	
		2.2.4	Habitat and Biodiversity Loss	33	

viii Contents

	2.3		mplex Issue with Complex Solution	33
	2.4	Toxic Reduction of Plastic Waste		
		2.4.1	Sources and Types of Toxic Substances in Plastic Waste	35
		2.4.2	Technologies and Methods for Reducing Toxicity in Plastic	
			Waste Management	37
	2.5	Efficie	ency of Current Plastic Waste Management	40
		2.5.1	Assessment of Existing Plastic Waste Management Systems	40
		2.5.2	Evaluation of Efficiency Metrics and Performance Indicators	41
		2.5.3	Challenges and Limitations in Current Practices	41
		2.5.4	Future Directions for Improving Plastic Waste Management	42
	2.6	Plastic	c Recycling	42
		2.6.1	Types and Recyclability of Plastics	44
		2.6.2	Environmental Benefits of Plastic Recycling	44
		2.6.3	Role of Stakeholders in Enhancing Recycling	44
	2.7	Concl	usion	46
	Refe	erences		47
3	Inno	ovative	Approaches to Plastic Waste Management	51
	3.1		uction	51
	3.2	Successful Local Experiences in Plastic Waste Management		52
		3.2.1	Community-Led Plastic Waste Initiatives	52
		3.2.2	Government-Led Policy Interventions	53
		3.2.3	Corporate and Industrial Best Practices	56
		3.2.4	Technological Innovations in Waste Management	57
	3.3		nable Disposal Solutions for Plastic Waste Management	59
	3.4	Innovations in Waste Treatment Technologies		62
		3.4.1	Advanced Recycling Technologies	63
		3.4.2	Nanotechnology in Plastic Decomposition	63
		3.4.3	Biotechnological Solutions	64
		3.4.4	Automation in Waste Processing	64
	3.5		ations in Plastic Pollution Control	65
	0.0	3.5.1	Policy-Based Strategies	66
		3.5.2	Ocean Clean-Up Technologies	67
		3.5.3	Microplastic Filtration Solutions	68
	3.6		c in Aquatic Environments	69
	2.0	3.6.1	Sources of Marine Pollution	70
		3.6.2	Impact on Marine Life and Ecosystems	72
		3.6.3	Global Cleanup and Prevention Efforts	74
	3.7		usion	76
		erences		76

Contents ix

1	Futi	Future Prospects for a Sustainable Environment			
	4.1	Introd	luction		
	4.2 Methods for Measuring Plastic Pollution			84	
		4.2.1	The Challenge of Microplastic Detection	84	
		4.2.2	Sampling and Collection Methods	84	
		4.2.3	Separation and Purification Techniques	85	
	4.3	Plastic	e Recycling Technologies: Research and Development	86	
		4.3.1	Mechanical Recycling	87	
		4.3.2	Chemical Recycling	87	
		4.3.3	Biological Recycling	89	
	4.4				
		4.4.1	Physical Remediation Techniques	91	
		4.4.2	Chemical and Advanced Oxidation Processes (AOPs)	91	
		4.4.3	Bioremediation and Phytoremediation	92	
		4.4.4	Emerging Approaches	92	
	4.5	Circul	ar Economy of Plastics	92	
	4.6		Implications and Recommendations	94	
		4.6.1	Policy Shortcomings and the Need for Integration	94	
		4.6.2	System Dynamics Modeling	95	
		4.6.3	Global Policy Landscape	96	
		4.6.4	Policy Implications and Recommendations	96	
	4.7		usion	98	
			usion	99	
	IVCIO	TOHCES		- フフ	

About the Authors

Dr. Navnath T. Hatvate, Ph.D. is an Assistant Professor at the Institute of Chemical Technology, Mumbai, Marathwada Campus, in Jalna. He holds a Master of Pharmacy and a Ph.D. from the Department of Pharmaceutical Sciences and Technology at the same institute. With 11 years of research experience and 6 years of teaching experience, he specializes in several areas. His research interests include the development of new chemical entities (NCE) and their analogues, modifications of excipients and their applications in drug delivery, and the use of artificial intelligence (AI) and machine learning (ML) in drug discovery and delivery. He is also focused on the process chemistry of active pharmaceutical ingredients (APIs) and intermediates, total synthesis of natural products and bioactive compounds, and the application of novel technologies in organic synthesis. Dr. Hatvate has published 52 research papers and authored 4 books. Additionally, he has guided 18 master's students in their research projects.

Mr. Ajinkya Madan Satdive is currently an Assistant Professor at the Institute of Chemical Technology, Marathwada Off Campus in Jalna. He is a dedicated professional specializing in polymer engineering and technology, with a diverse background encompassing both industry and academia. With nearly 8 years of combined experience, his current focus is on the modification of biopolymers, material modification techniques, polymer processing methodologies, synthesis strategies, elucidating structure-property relationships, and the development of polymer blends and alloys. He has taught various subjects, including polymer processing, polymer blends and alloys, high polymer chemistry, and polymer science and technology. To date, he has published 8 international peer-reviewed articles and 6 book chapters.

Dr. Hemantkumar N. Akolkar, Ph.D. is currently working as an Associate Professor in the Department of Chemistry at Rayat Shikshan Sanstha's Abasaheb Marathe Arts and New Commerce Science College, Maharashtra, India. He is an acclaimed academician and researcher who has worked for the last 14 years at both undergraduate and postgraduate

xii About the Authors

levels. He has published 55+ research papers in national and international journals and conferences of repute. His areas of interest are heterocyclic chemistry, synthetic organic chemistry, and green chemistry. He is a reviewer of several journals of international repute in Chemistry.

A. K. Haghi is a retired Professor and has written, co-written, edited, or co-edited more than 1000 publications, including books, book chapters, and papers in refereed journals with over 4200 citations and h-index of 34, according to the Google Scholar database. Prof. Haghi holds a B.Sc. in urban and environmental engineering from the University of North Carolina (USA) and holds two M.Sc. degrees, one in mechanical engineering from North Carolina State University (USA) and another one in applied mechanics, acoustics, and materials from the Université de Technologie de Compiègne (France). He was awarded a Ph.D. in engineering sciences at Université de Franche-Comté (France).

Professor Haghi's extensive educational background and supervisory roles underscore his expertise and contributions to the field of engineering sciences. He is appointed as Honorary Research Associate (HRA) at University of Coimbra, Portugal. He is a regular reviewer of leading international journals.