

SPRINGER BRIEFS IN MOLECULAR SCIENCE

Arnab De
Rituparna Bose
Ajeet Kumar
Subho Mozumdar

Targeted Delivery of Pesticides Using Biodegradable Polymeric Nanoparticles



Springer

SpringerBriefs in Molecular Science

For further volumes:
<http://www.springer.com/series/8898>

Arnab De · Rituparna Bose
Ajeet Kumar · Subho Mozumdar

Targeted Delivery of Pesticides Using Biodegradable Polymeric Nanoparticles

Arnab De
Department of Immunology
Columbia University
New York, NY
USA

Ajeet Kumar
Subho Mozumdar
Department of Chemistry
University of Delhi
Delhi
India

Rituparna Bose
Department of Earth and Environmental
Science
The City University of New York
New York, NY
USA

ISSN 2191-5407
ISBN 978-81-322-1688-9
DOI 10.1007/978-81-322-1689-6
Springer New Delhi Heidelberg New York Dordrecht London

ISSN 2191-5415 (electronic)
ISBN 978-81-322-1689-6 (eBook)

Library of Congress Control Number: 2013951797

© The Author(s) 2014

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. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's 'location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law. 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.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

*Dedicated to
late Professor Larry Grossman,
Distinguished Professor and ex-Chairman,
Department of Biochemistry,
School of Hygiene and Public Health,
Johns Hopkins University*

Preface

Pesticides have revolutionized life on this planet; however, they have also proven to be toxic for human health and environment. Indeed, the extent and severity of the toxicity was declared at the Stockholm Convention on Persistent Organic Pollutants where 9 of the 12 most dangerous and toxic organic chemicals were found to be pesticides. Traditionally, pesticides have been directed at a specific pest's life cycle as this required less pesticide and was considered to be more eco-friendly. However, this would not prevent pesticides from drifting away and potentially posing grave risks to the environment. In this book, we describe recent developments of controlled release nanoparticulate formulation of pesticides using biodegradable polymers as carrier. Technologies focusing on controlled-release of pesticide have two advantages: the pesticides are intact until sprayed and targets only the plants the pesticides are meant to protect. We have generalized the concepts to make the book useful in the post-graduate classes taught in our university and for advanced professionals alike.

While nanoparticles have revolutionized drug delivery effectively chaperoning the drug to target organs, delivery of pesticides to its intended site of action is still in the process of initial exploration. Additionally, there lies the concern of environmental safety of the fate of the pesticide-carrier. Consequently, while there have been books written on drug delivery, there are almost no available books on the topic of pesticide-delivery.

This book (a result of collaboration between scientists from Columbia University, City College of New York, and University of Delhi, India) is the first to focus exclusively on environmentally benign delivery of pesticides (controlled-release nanoparticulate formulation of pesticides using biodegradable polymers as carriers).

Acknowledgments

Some of the work embodied in this book, especially the one dealing with the role of microemulsions in synthesizing nanoparticles and using them for preparing nano-formulations of agrochemicals, has been carried out in my laboratory at the Department of Chemistry, University of Delhi. The idea of working in this field was introduced by Dr. P. K. Patanjali of IPFT, Gurgaon and his students Dr. Amit Saxena and Dr. Pooja Saxena. The funds for this work were provided by the Department of Biotechnology, Government of India and I personally thank D.B.T. and the Scientific Advisors Dr. R. R. Sinha and Dr. Dhananjay Tiwari for giving us proper encouragement for doing this work. I would also like to express my gratitude to my current Head of the Department, Professor S. M. S. Chauhan for providing us with the necessary infrastructure for setting up a laboratory where this work could be carried out. My students (both postgraduate and undergraduate) deserve a special mention, as it is their untiring effort that has resulted in this work. All of us would like to sincerely thank Mr. Sushil Mishra for helping us with all the data and also meticulously typing the entire manuscript. I also take the opportunity to thank my wife, Mrs. Jayati Mozumdar and my sons, Deepto and Aaloke, for providing me with a proper ambience and all the emotional support for writing this work. Finally, I must thank my parents Dr. Monojit Mozumdar and Dr. (Mrs.) Anjali Mozumdar for inculcating the right values in me. I decided to dedicate this book in the memory of my postdoctoral mentor, late Professor Larry Grossman. He taught me the art of doing Science and the spirit of never to give up before a goal is reached.

Subho Mozumdar

Contents

1	Introduction	1
	References	4
2	Worldwide Pesticide Use	5
3	Pesticide Application in India	7
	References	9
4	Food Contamination and Wastage by Insects	11
	References	13
5	Pesticide Formulations	15
5.1	Conventional Formulations	15
5.1.1	Granules	15
5.1.2	Solution Concentrates	16
5.1.3	Emulsifiable Concentrates	17
5.1.4	Wettable Powders	18
5.1.5	Suspension Concentrates	18
5.2	New Generation Formulations	20
5.2.1	Suspoemulsions	21
5.2.2	Oil-in-Water Emulsions	21
5.2.3	Microemulsions	22
5.2.4	Multiple Emulsions	22
	References	23
6	Trends and Limitations in Chemical-Based Pest Management	25
	References	26
7	Biological Control of Insect Pests	27
	References	28

8	Management of Insect Pests Using Nanotechnology: As Modern Approaches	29
8.1	Additional Applications of Nanotechnology in the Field of Agriculture	31
8.1.1	Precision Farming.	31
8.2	Nanomaterials: Antimicrobial Agents for Plant Pathogens	31
	References	32
9	A Brief Overview of Nanotechnology.	35
	References	36
10	Nanoparticulate Delivery Systems	37
10.1	Delivery Systems	38
10.1.1	Hydrogel	38
10.1.2	Dendrimers	39
10.1.3	Liposomes	40
10.1.4	Niosomes.	40
10.1.5	Polymersomes	41
10.1.6	Solid Lipid Nanoparticle	42
10.1.7	Micro- and Nanoemulsions	43
10.1.8	Micelles	44
10.1.9	Carbon Nanomaterials.	44
10.2	Synthesis of Nanomaterials	45
10.2.1	Top-Down Approach	45
10.2.2	Bottom-Up Approach	45
10.2.3	Hybrid Approach	46
10.3	Dispersion of Preformed Polymers	46
10.3.1	Emulsification/Solvent Evaporation	46
10.3.2	Solvent Displacement, Diffusion, or Nanoprecipitation	47
10.3.3	Emulsification/Solvent Diffusion	47
10.3.4	Salting-Out	48
10.3.5	Dialysis.	48
10.3.6	Supercritical Fluid Technology.	49
10.4	Emulsion Polymerization.	49
10.4.1	Conventional Emulsion Polymerization	50
10.4.2	Surfactant-Free Emulsion Polymerization	50
10.4.3	Miniemulsion Polymerization.	50
10.4.4	Microemulsion Polymerization	51
10.4.5	Interfacial Polymerization	51
	References	52

11	Nanoparticulate Formulations for Pesticide Applications	59
11.1	Microemulsion	59
11.1.1	Surfactants in Microemulsion	60
11.1.2	Role of Cosurfactant	61
11.1.3	Nanoemulsions	70
11.1.4	Nanoencapsulation	74
11.1.5	Nanosilica	78
	References	81
12	Characterization and In Vitro Release Techniques for Nanoparticulate Systems	85
12.1	Dynamic Light Scattering	85
12.2	Zeta Potential.	87
12.3	Atomic Force Microscope	88
12.4	Electron Microscopy	89
12.4.1	Transmission Electron Microscopy	90
12.4.2	Scanning Electron Microscope	90
12.5	Energy Dispersive X-ray (EDX).	92
12.6	Dissolution and Release Kinetics	93
12.6.1	Goodness-of-Fit Model-Dependent Approach.	95
12.6.2	Zero-Order Model	95
12.6.3	First-Order Model.	95
12.6.4	Higuchi Model.	96
12.6.5	Hixson-Crowell model	97
12.6.6	Korsmeyer–Peppas Model for Mechanism of Drug Release	97
	References	98
	About the Authors.	99

Figures

Fig. 2.1	Consumption of pesticides in the Indian scenario	5
Fig. 2.2	Worldwide consumption of pesticides	6
Fig. 3.1	Chemical structure of a gamma hexachlorocyclohexane (HCH) and b dichlorodiphenyltrichloroethane (DDT)	8
Fig. 3.2	Chemical structure of a parathion and b malathion	8
Fig. 11.1	Hypothetical pseudo-ternary phase diagram of an oil/surfactant/water system showing regions of microemulsions and emulsion phases (Rane and Anderson 2008; Lawrence and Rees 2000; Prince 1975).	60
Fig. 11.2	Chemical structure of permethrin	61
Fig. 11.3	Chemical structure of ammonium glycyrrhizinate (European-Pharmacopoeia 2005).	62
Fig. 11.4	Chemical structure of a Triton X-100 and b sodium dodecyl benzene sulfonate (Sigma Chemical; Sigma-Aldrich)	63
Fig. 11.5	Chemical structure of azadirachtin (Nisbet 2000)	64
Fig. 11.6	Chemical structure of rotenone	68
Fig. 11.7	Chemical structure of chlorpyrifos	69
Fig. 11.8	Chemical structure of β -cypermethrin a (R)-alcohol(1S)-cis-acid; b (R)-alcohol(1S)-trans-acid; c (S)-alcohol(1R)-cis-acid; d (S)-alcohol(1R)-trans-acid (Wood)	70
Fig. 11.9	Chemical structure of glyphosate isopropylamine	71
Fig. 11.10	Chemical structure of bifenthrin	73
Fig. 11.11	Chemical structure of triazophos	73
Fig. 11.12	Chemical structure of acephate	74
Fig. 11.13	Chemical structure of lansiumamide B (Matsui et al. 2013).	77
Fig. 11.14	Molecular structure of avermectin a Avermectin B1 _a and b Avermectin B1 _b (Putter et al. 1981)	79
Fig. 11.15	Chemical structure of validamycin (Liu et al. 2006)	80

Fig. 12.1	DLS picture of silica nanoparticle suspended in distilled water	87
Fig. 12.2	TEM pictures of colloidal silica	91
Fig. 12.3	EDX pattern of colloidal silica	93
Fig. 12.4	Schematic representation of solid dissolution	94