

# **The Handbook of Environmental Chemistry**

**Founded by Otto Hutzinger**

**Editors-in-Chief: Damià Barceló • Andrey G. Kostianoy**

**Volume 23**

## **Advisory Board:**

**Jacob de Boer, Philippe Garrigues, Ji-Dong Gu,  
Kevin C. Jones, Thomas P. Knepper, Alice Newton,  
Donald L. Sparks**

# The Handbook of Environmental Chemistry

## Recently Published and Forthcoming Volumes

**Global Risk-Based Management of Chemical Additives II: Risk-Based Assessment and Management Strategies**  
Volume Editors: B. Bilitewski, R.M. Darbra, and D. Barceló  
Vol. 23, 2013

**Chemical Structure of Pelagic Redox Interfaces: Observation and Modeling**  
Volume Editor: E.V. Yakushev  
Vol. 22, 2013

**The Llobregat: The Story of a Polluted Mediterranean River**  
Volume Editors: S. Sabater, A. Ginebreda, and D. Barceló  
Vol. 21, 2012

**Emerging Organic Contaminants and Human Health**  
Volume Editor: D. Barceló  
Vol. 20, 2012

**Emerging and Priority Pollutants in Rivers: Bringing Science into River Management Plans**  
Volume Editors: H. Guasch, A. Ginebreda, and A. Geiszinger  
Vol. 19, 2012

**Global Risk-Based Management of Chemical Additives I: Production, Usage and Environmental Occurrence**  
Volume Editors: B. Bilitewski, R.M. Darbra, and D. Barceló  
Vol. 18, 2012

**Polyfluorinated Chemicals and Transformation Products**  
Volume Editors: T.P. Knepper and F.T. Lange  
Vol. 17, 2012

**Brominated Flame Retardants**  
Volume Editors: E. Eljarrat and D. Barceló  
Vol. 16, 2011

**Effect-Directed Analysis of Complex Environmental Contamination**  
Volume Editor: W. Brack  
Vol. 15, 2011

**Waste Water Treatment and Reuse in the Mediterranean Region**  
Volume Editors: D. Barceló and M. Petrovic  
Vol. 14, 2011

**The Ebro River Basin**  
Volume Editors: D. Barceló and M. Petrovic  
Vol. 13, 2011

**Polymers – Opportunities and Risks II: Sustainability, Product Design and Processing**  
Volume Editors: P. Eyerer, M. Weller, and C. Hübner  
Vol. 12, 2010

**Polymers – Opportunities and Risks I: General and Environmental Aspects**  
Volume Editor: P. Eyerer  
Vol. 11, 2010

**Chlorinated Paraffins**  
Volume Editor: J. de Boer  
Vol. 10, 2010

**Biodegradation of Azo Dyes**  
Volume Editor: H. Atacag Erkurt  
Vol. 9, 2010

**Water Scarcity in the Mediterranean: Perspectives Under Global Change**  
Volume Editors: S. Sabater and D. Barceló  
Vol. 8, 2010

**The Aral Sea Environment**  
Volume Editors: A.G. Kostianoy and A.N. Kosarev  
Vol. 7, 2010

**Alpine Waters**  
Volume Editor: U. Bundi  
Vol. 6, 2010

# Global Risk-Based Management of Chemical Additives II

Risk-Based Assessment and Management  
Strategies

Volume Editors: Bernd Bilitewski · Rosa Mari Darbra ·  
Damià Barceló

With contributions by

S. Åström · D. Baderna · N.G. Bakhtyari · D. Barceló · E. Benfenati ·  
B. Bilitewski · E. Boriani · E. Capri · J. Casal · A. Colacci ·  
R.M. Darbra · J.L. Domingo · Z. Fonseca · H. Friege · A. Ginebreda ·  
N. Golbamaki · M. Gros · V. Grundmann · D. Guillén · S. Heise ·  
R. Hooda · A. Kersten · U. Lahl · H.F. Larsen · M. Lindblad ·  
S. Maggioni · C.F. Mahler · A. Mishra · M. Nadal · N.B. Ngoc ·  
H.-G. Ni · S. Pandey · M. Petrovic · H.-J. Putz · J. Rovira · T. Rydberg ·  
S. Rydin · S. Schabel · A.S. Schueler · M. Schuhmacher · X. Seguí ·  
X. Segui · S. Sthiannopkao · N.A. Suciu · N. Suciu · T. Tanaka ·  
T. Tanaku · H. Tien · N.T.D. Trang · M. Trevisan · M. Vaccari ·  
E. van der Voet · L. van Oers · J. Westerdahl · A. Zehm · E.Y. Zeng ·  
B. Zeschmar-Lahl

*Editors*

Prof. Dr. Ing. habil. Dr. h.c. Bernd Bilitewski  
Dresden University of Technology  
Institute of Waste Management and  
Contaminated Site Treatment  
Pirna, Germany

Assoc. Prof. Dr. Rosa Mari Darbra  
CERTEC – Centre for Technological  
Risk Studies  
UPC – Polytechnic University of  
Catalonia  
Barcelona, Spain

Prof. Dr. Damià Barceló  
Department of Environmental Chemistry  
IDAEA-CSIC  
Barcelona, Spain  
and  
Catalan Institute for Water Research (ICRA)  
Scientific and Technological Park of the  
University of Girona  
Girona, Spain

The Handbook of Environmental Chemistry

ISSN 1867-979X

ISSN 1616-864X (electronic)

ISBN 978-3-642-34571-5

ISBN 978-3-642-34572-2 (eBook)

DOI 10.1007/978-3-642-34572-2

Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2012956537

© Springer-Verlag Berlin Heidelberg 2013

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](http://www.springer.com))

*In Memoriam Otto Hutzinger 1933–2012*



---

## Editors-in-Chief

Prof. Dr. Damià Barceló

Department of Environmental Chemistry  
IDAEA-CSIC  
C/Jordi Girona 18–26  
08034 Barcelona, Spain  
and  
Catalan Institute for Water Research (ICRA)  
H20 Building  
Scientific and Technological Park of the  
University of Girona  
Emili Grahit, 101  
17003 Girona, Spain  
*dbcqam@cid.csic.es*

Prof. Dr. Andrey G. Kostianoy

P.P. Shirshov Institute of Oceanology  
Russian Academy of Sciences  
36, Nakhimovsky Pr.  
117997 Moscow, Russia  
*kostianoy@gmail.com*

## Advisory Board

Prof. Dr. Jacob de Boer

IVM, Vrije Universiteit Amsterdam, The Netherlands

Prof. Dr. Philippe Garrigues

University of Bordeaux, France

Prof. Dr. Ji-Dong Gu

The University of Hong Kong, China

Prof. Dr. Kevin C. Jones

University of Lancaster, United Kingdom

Prof. Dr. Thomas Knepper

University of Applied Science, Fresenius, Idstein, Germany

Prof. Dr. Alice Newton

University of Algarve, Faro, Portugal

Prof. Dr. Donald L. Sparks

Plant and Soil Sciences, University of Delaware, USA





# **The Handbook of Environmental Chemistry**

## **Also Available Electronically**

*The Handbook of Environmental Chemistry* is included in Springer's eBook package *Earth and Environmental Science*. If a library does not opt for the whole package, the book series may be bought on a subscription basis.

For all customers who have a standing order to the print version of *The Handbook of Environmental Chemistry*, we offer free access to the electronic volumes of the Series published in the current year via SpringerLink. If you do not have access, you can still view the table of contents of each volume and the abstract of each article on SpringerLink ([www.springerlink.com/content/110354/](http://www.springerlink.com/content/110354/)).

You will find information about the

- Editorial Board
- Aims and Scope
- Instructions for Authors
- Sample Contribution

at [springer.com](http://springer.com) ([www.springer.com/series/698](http://www.springer.com/series/698)).

All figures submitted in color are published in full color in the electronic version on SpringerLink.

## **Aims and Scope**

Since 1980, *The Handbook of Environmental Chemistry* has provided sound and solid knowledge about environmental topics from a chemical perspective. Presenting a wide spectrum of viewpoints and approaches, the series now covers topics such as local and global changes of natural environment and climate; anthropogenic impact on the environment; water, air and soil pollution; remediation and waste characterization; environmental contaminants; biogeochemistry; geoecology; chemical reactions and processes; chemical and biological transformations as well as physical transport of chemicals in the environment; or environmental modeling. A particular focus of the series lies on methodological advances in environmental analytical chemistry.



## Series Preface

With remarkable vision, Prof. Otto Hutzinger initiated *The Handbook of Environmental Chemistry* in 1980 and became the founding Editor-in-Chief. At that time, environmental chemistry was an emerging field, aiming at a complete description of the Earth's environment, encompassing the physical, chemical, biological, and geological transformations of chemical substances occurring on a local as well as a global scale. Environmental chemistry was intended to provide an account of the impact of man's activities on the natural environment by describing observed changes.

While a considerable amount of knowledge has been accumulated over the last three decades, as reflected in the more than 70 volumes of *The Handbook of Environmental Chemistry*, there are still many scientific and policy challenges ahead due to the complexity and interdisciplinary nature of the field. The series will therefore continue to provide compilations of current knowledge. Contributions are written by leading experts with practical experience in their fields. *The Handbook of Environmental Chemistry* grows with the increases in our scientific understanding, and provides a valuable source not only for scientists but also for environmental managers and decision-makers. Today, the series covers a broad range of environmental topics from a chemical perspective, including methodological advances in environmental analytical chemistry.

In recent years, there has been a growing tendency to include subject matter of societal relevance in the broad view of environmental chemistry. Topics include life cycle analysis, environmental management, sustainable development, and socio-economic, legal and even political problems, among others. While these topics are of great importance for the development and acceptance of *The Handbook of Environmental Chemistry*, the publisher and Editors-in-Chief have decided to keep the handbook essentially a source of information on "hard sciences" with a particular emphasis on chemistry, but also covering biology, geology, hydrology and engineering as applied to environmental sciences.

The volumes of the series are written at an advanced level, addressing the needs of both researchers and graduate students, as well as of people outside the field of "pure" chemistry, including those in industry, business, government, research establishments, and public interest groups. It would be very satisfying to see these volumes used as a basis for graduate courses in environmental chemistry. With its high standards of scientific quality and clarity, *The Handbook of*

*Environmental Chemistry* provides a solid basis from which scientists can share their knowledge on the different aspects of environmental problems, presenting a wide spectrum of viewpoints and approaches.

*The Handbook of Environmental Chemistry* is available both in print and online via [www.springerlink.com/content/110354/](http://www.springerlink.com/content/110354/). Articles are published online as soon as they have been approved for publication. Authors, Volume Editors and Editors-in-Chief are rewarded by the broad acceptance of *The Handbook of Environmental Chemistry* by the scientific community, from whom suggestions for new topics to the Editors-in-Chief are always very welcome.

Damià Barceló  
Andrey G. Kostianoy  
Editors-in-Chief

# Volume Preface

This second volume of this book, *Global Risk-Based Management of Chemical Additives*, presents the results obtained after 3 years of research conducted during the EC funded RISKCYCLE project (Risk-based management of chemicals and products in a circular economy at a global scale).

The main objective of this project was to establish and coordinate a global network of European and international experts and stakeholders from worldwide countries to assess the risks of hazardous chemicals and additives contained in different daily products. The transport of these compounds is given at a global scale, increasing their potential damage to the environment and citizens all over the world.

In the first part of this book, different models related to the assessment of the potential risk posed by the chemical additives are presented. These models come from different fields of expertise: toxicology, risk assessment, chemicals fate and exposure, life cycle assessment, economics, etc. The potential benefits of the different models as well as their drawbacks are analyzed in order to select some of them for the application to particular case studies.

Some aspects related to the chemicals regulations are also reviewed, especially those affecting the European new chemicals legislation, such as REACH (regulation concerning the Registration, Evaluation, Authorizations and restriction of Chemicals). Some socioeconomic aspects are also treated in relation to the need of chemicals for the society.

In the second part, specific case studies in which the aforementioned models have been applied are presented. The results of such application as well as their reliability are discussed. Toxicological studies in Italy, risk assessment of electronic waste in China, or disposal of bearing lamps in India are some examples of selected scenarios. We hope that the scientific community finds in this book a source of information and inspiration to continue the research on chemical additives contained in products around the world.

Finally, we would like to thank all the authors who have contributed to this book, for their effort in gathering the information and elaborating the different chapters. We are also grateful that the advisory board of the project was helping us to keep

realism in the project discussions. We would like to mention especially Dr. Jürgen Büsing, scientific officer from the Commission DG Research, for his help and his guiding comments.

Georges Deschamps  
EC Project Officer

B. Bilitewski, R.M. Darbra, D. Barceló  
Editors

# Contents

|   |     |
|---|-----|
| <b>Introduction</b> .....   | 1   |
| D. Barceló, R.M. Darbra, B. Bilitewski, V. Grundmann, and A. Zehm   |     |
| <b>Part I Methodologies for the Global Management Strategies</b>  |     |
| <b>Life Cycle Assessment of Additives: Methodology and Data</b> .....   | 7   |
| Ester van der Voet, Laurant van Oers, Tomas Rydberg, Jenny Westerdahl, and Henrik Fred Larsen   |     |
| <b>Characterization of Environmental Exposure: Measuring Versus Modeling</b> .....  | 25  |
| Daniel Guillén, Antoni Ginebreda, Rosa M. Darbra, Meritxell Gros, Mira Petrovic, and Damià Barceló  |     |
| <b>Environmental Fate Models</b> .....  | 47  |
| N. Suciú, T. Tanaka, M. Trevisan, M. Schuhmacher, M. Nadal, J. Rovira, X. Seguí, J. Casal, R.M. Darbra, and E. Capri                        |     |
| <b>Toxicological and Ecotoxicological Studies for Additives</b> .....   | 73  |
| Nazanin Golbamaki Bakhtyari, Diego Baderna, Elena Boriani, Marta Schuhmacher, Susanne Heise, and Emilio Benfenati                           |     |
| <b>A Revision of Current Models for Environmental and Human Health Impact and Risk Assessment for Application to Emerging Chemicals</b> ... | 91  |
| J. Rovira, M. Nadal, J.L. Domingo, T. Tanaka, N.A. Suciú, M. Trevisan, E. Capri, X. Seguí, R.M. Darbra, and M. Schuhmacher                  |     |
| <b>Are Chemicals in Products Good or Bad for the Society? – An Economic Perspective</b> .....   | 109 |
| Stefan Åström, Maria Lindblad, Jenny Westerdahl, and Tomas Rydberg  |     |
| <b>RISKCYCLE and EU Legislation</b> .....   | 137 |
| Uwe Lahl and Barbara Zeschmar-Lahl  |     |

## Part II Case Studies

|   |     |
|---|-----|
| <b>Two Sides of One Coin: Relations Between Hazardous Substances and Valuable Resources</b> .....                                       | 155 |
| Henning Friege  |     |
| <b>Toxicological Characterization of Waste-Related Products Using Alternative Methods: Three Case Studies</b> .....                     | 171 |
| Diego Baderna, Nazanin Golbamaki, Silvia Maggioni, Monica Vaccari, Annamaria Colacci, and Emilio Benfenati                              |     |
| <b>LCA Case Study on Printed Matter</b> .....   | 207 |
| Henrik Fred Larsen  |     |
| <b>LCA Case Study Cushion Vinyl Floor Covering and DEHP</b> .....   | 223 |
| Lauran van Oers and Ester van der Voet  |     |
| <b>Chemicals in Leather: International Trends on Risk-Based Control and Management</b> .....  | 245 |
| Stefan Rydin  |     |
| <b>Managing E-Waste in Developed and Developing Countries</b> .....   | 263 |
| Suthipong Sthiannopkao  |     |
| <b>Mass Emissions of Pollutants from E-Waste Processed in China and Human Exposure Assessment</b> .....                                 | 279 |
| Hong-Gang Ni and Eddy Y. Zeng   |     |
| <b>Tracking Global Flows of E-Waste Additives by Using Substance Flow Analysis, with a Case Study in China</b> .....                    | 313 |
| H. Tien, S. Heise, X. Seguí, J. Casal, R.M. Darbra, N. Suciú, E. Capri, M. Trevisan, M. Schuhmacher, M. Nadal, and J. Rovira            |     |
| <b>Human and Environmental Impact Produced by E-Waste Releases at Guiyu Region (China)</b> .....  | 349 |
| N. Suciú, E. Capri, M. Trevisan, T. Tanaka, H. Tien, S. Heise, M. Schuhmacher, M. Nadal, J. Rovira, X. Seguí, J. Casal, and R.M. Darbra |     |
| <b>In Search of Zero Waste: An Experiment in Progress</b> .....   | 385 |
| C.F. Mahler, A.S. Schueler, and Z. Fonseca  |     |
| <b>Mineral Oil in Board and Paper Recycling</b> .....   | 399 |
| Antje Kersten, Hans-Joachim Putz, and Samuel Schabel  |     |



**Proposed Plan for Disposal of Mercury- Bearing Lamps for India** ..... 419  
Suneel Pandey, Rakesh Hooda, and Arabinda Mishra

**Study of the Substitution of Fossil Fuels by RDF Produced  
from Municipal Solid Waste of Hanoi: A Case Study** ..... 441  
Nguyen Thi Diem Trang and N.B. Ngoc

**Part III Conclusions**

**Conclusions** ..... 465  
B. Bilitewski, A. Zehm, V. Grundmann, R.M. Darbra, and D. Barceló

**Index** ..... 473