

Sanjay K. Sharma • Rashmi Sanghi  
*Editors*

# Advances in Water Treatment and Pollution Prevention



Springer

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Sanjay K. Sharma  
Jaipur Engineering College & Research  
Centre  
JECRC Foundation  
Jaipur  
India

Rashmi Sanghi  
Indian Institute of Technology Kanpur  
UP  
India

ISBN 978-94-007-4203-1

ISBN 978-94-007-4204-8 (eBook)

DOI 10.1007/978-94-007-4204-8

Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2012942032

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Printed on acid-free paper

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*This book is for the coming generations, to  
make them aware about the 'cost' of water.*

*– Sanjay K. Sharma and Rashmi Sanghi*

# Preface

*Anyone who can solve the problems of water will be worthy of two Nobel prizes – one for peace and one for science.*

John F. Kennedy

*When the well is dry, we learn the worth of water.*

Benjamin Franklin

The mighty words of John F. Kennedy and Benjamin Franklin underline quite simply, and yet very powerfully, how important water is for the survival of our planet and its species and invite us to take measure against the dramatic consequences of water shortage.

Editing this book has been a very special experience for us because it has meant posing ourselves a crucial question: ‘how could we live without water?’

Nowadays, the world water crisis has assumed alarming proportions and certainly two causes in particular have played a crucial role in its intensification:

- The World’s growing population, and the consequent increase in water consumption and sanitation problems
- The fast-growing process of industrialization and development activities, which has led to water shortage and water pollution

The latter has been especially challenging because of its tangible and dramatic impact on ecosystems, human well-being and economies. And it is on the effects of water pollution that this book focuses its attention, examining what preventive measures can be taken against water pollution and stressing the need to implement greener water treatments.

The high quality chapters gathered in this volume make *Advances in Water Treatment and Pollution Prevention* a valuable resource to academic researchers, students, institutions, environmentalists, and anyone interested in environmental policies aimed at safeguarding both the quality and the quantity of water. We are

positive that the book will provide an insightful analysis of Water Pollution and of its treatments as well as of the processes that have been studied, optimized and developed so far to sustain our environment.

We sincerely welcome feedback from our valuable readers and critics.

Jaipur, India  
Kanpur, India

Sanjay K. Sharma  
Rashmi Sanghi

# Acknowledgements

The time has come to express our sincere gratitude to all our friends, supporters and well wishers. We are heartily obliged for the support they have shown us while writing *Advances in Water Treatment and Pollution Prevention*.

First of all, we would like to thank all the esteemed contributors of this book. Without their contribution none of this would have been possible.

Professor Sharma would like to start by expressing his sincere gratitude to his teachers, Dr. R.K. Bansal, Dr. R.V. Singh, Dr. R.K. Bhardwaj, and Dr. Saraswati Mittal, the *Gurus* behind all his academic achievements and publications.

He then acknowledges Ackmez Mudhoo, Dr. Nabuk Eddy, Dr. Dong Chen, Dr. V.K. Garg, and all his friends and colleagues at the Jaipur Engineering College and Research Centre (JECRC) for their active interest and moral support.

Finally, he praises his family. His parents, Dr. M.P. Sharma and Mrs. Parmeshwari Devi, his wife Dr. Pratima Sharma, and all his family members for their never ending encouragement, moral support and patience over the months spent writing this book. A special thank you goes to his children, Kunal and Kritika: valuable moments of their lives have been missed because of his busy schedule.

Professor Sanghi would like to thank her family, who supported her all along. Her children, Surabhi and Udit, for their admirable patience and understanding that gave her the strength to face this challenging project. Her husband, Dheeraj Sanghi, whose encouragement and optimism at every stage have been precious. Her family friend, Prof. Sudhir Jain, for her support, insights and critical comments. Thank you also to her group of friends at IIT Kanpur for the relaxing walks they took together. Last but not least, a big thank you goes to Dr. Sanjay Sharma, editor of this book who 'dragged' her into this amazing project.

We are beholden to many other people whose names we have not been able to mention here but whose guidance has been very valuable. Finally, we would like to thank you our valuable readers and critics for encouraging us to do more and more research on this issue.

*Save Water! Think Green!*

Sanjay K. Sharma  
Rashmi Sanghi  
(Editors)

# Abbreviations

Alum	Aluminum Sulfate
AOT	Advanced oxidation technology
AR88	Acid red 88
BDD	Boron-doped diamond
BEA-SECT	Background electrolyte-assisted sonoelectrochemical treatment
BOD	Biological oxygen demand
CI-MBE	Mass balance error based on chlorine atoms, %
CNTs	Carbon nanotubes
COD	Chemical oxygen demand
DBS	Dodecylbenzenesulfonate
DCE	Dichloroethylene
DE	Degradation efficiency, %
DF	Diclofenac
DLVO	Derjaguin, Landau, Verwey and Overbeek
DNOC	4,6-Dinitro-o-cresol
DOE	Department of Environment
ECT	Electrochemical treatment
EDTA	Ethylenediaminetetraacetic acid
f	Frequency
F	Faraday constant, C mol <sup>-1</sup>
FC	Fractional conversion, %
GC	Gaseous chromatography
GO	Graphene oxide
HPLC	High performance liquid chromatography
I <sub>a</sub>	Ultrasound intensity
IBP	Ibuprofen
IC	Ion chromatography
MB	Methylene blue



MCP	Monocrotophos
MDB	Meldola blue
MG	Malachite green
MO	Methylene orange
MTBE	Methyl <i>tert</i> -butyl ether
MWCNT	Multi-walled carbon nanotube
NBB	Naphthol blue back
NPE	Nonylphenol ethoxylate
ODE	Ordinary differential equation
OG	Orange G
PAC	Polyaluminum chloride
PBM	Population Balance Model
p-CBA	p-Chlorobenzoic acid
PCE	Perchloroethylene
PCP	Pentachlorophenol
POMB	Palm oil mill boiler
POME	Palm oil mill effluent
PZT	Lead ziconate titanate
RB5	Reactive black 5
SCE	Saturated calomel electrode
S <sub>Cl</sub>	Chloride ion selectivity
SCT	Sonochemical treatment
SECT	Sonoelectrochemical treatment without background electrolyte addition
SEF	Sonoelectro-Fenton
SERS	Surface-enhanced Raman spectroscopy
TCE	Trichloroethylene
TEM	Transmission electron microscopy
TOC	Total organic carbon
UV	Ultraviolet
V <sub>A-C</sub>	Cathode-anode voltage
zpc	Zero point charge

# Contributors

**Mohammed Al-Abri** Petroleum and Chemical Engineering Department, College of Engineering, Sultan Qaboos University, Muscat, Oman

**M. Ashokkumar** School of Chemistry, University of Melbourne, Melbourne, Australia

**Jesús Beltrán-Heredia** Department of Chemical Engineering and Physical Chemistry, University of Extremadura, Badajoz, Spain

**P. Bonete** Grupo de Nuevos Desarrollos Tecnológicos en Electroquímica: Sono-electroquímica y Bioelectroquímica, Grupo de Fotoquímica y Electroquímica de semiconductores, Departamento de Química Física e Instituto de Electroquímica, Universidad de Alicante, Alicante, Spain

**Jeanette Brown** Manhattan College, Riverdale, NY, USA

**Fang Cai** School of Chemical Engineering and Technology, Tianjin University, Tianjin, People's Republic of China

**Shaoan Cheng** State Key Laboratory of Clean Energy Utilization, Department of Energy Engineering, Zhejiang University, Hangzhou, China

**Mei Fong Chong** Department of Chemical and Environmental Engineering, Faculty of Engineering, The University of Nottingham, Semenyih, Selangor, Malaysia

**Adrian Covaci** Toxicological Centre, University of Antwerp, Antwerp, Belgium

**Giovanni De Feo** Department of Industrial Engineering, University of Salerno, Salerno, Italy

**M.D. Esclapez** Grupo de Nuevos Desarrollos Tecnológicos en Electroquímica: Sono-electroquímica y Bioelectroquímica, Grupo de Fotoquímica y Electroquímica de semiconductores, Departamento de Química Física e Instituto de Electroquímica, Universidad de Alicante, Alicante, Spain

**J. González-García** Grupo de Nuevos Desarrollos Tecnológicos en Electroquímica: Sonoelectroquímica y Bioelectroquímica, Departamento de Química Física e Instituto de Electroquímica, Universidad de Alicante, Alicante, Spain

**Tingyue Gu** Department of Chemical and Biomolecular Engineering, Ohio University, Athens, OH, USA

**Daniel J. Hassett** Department of Molecular Genetics, Biochemistry and Microbiology, University of Cincinnati College of Medicine, Cincinnati, OH, USA

**Nidal Hilal** Centre for Water Advanced Technologies and Environmental Research (CWATER), College of Engineering, Swansea University, Swansea, United Kingdom

**Liping Huang** Key Laboratory of Industrial Ecology and Environmental Engineering, Ministry of Education (MOE), School of Environmental Science and Technology, Dalian University of Technology, Dalian, China

**Yulan Ji** School of Chemical Engineering and Technology, Tianjin University, Tianjin, People's Republic of China

**Jing Li** Engineering Department, China Tianjin Chemical Engineering Design Institute, Tianjin University, Tianjin, People's Republic of China

**Giusy Lofrano** Civil and Environmental Engineer, Salerno, Italy

**Ling Wei Low** School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia

**Tulika Malviya** University of Allahabad, Allahabad, India

**Ackmez Mudhoo** Department of Chemical and Environmental Engineering, Faculty of Engineering, University of Mauritius, Mauritius

**B. Neppolian** SRM Research Institute, SRM University, Kattankulathur, Chennai, India

**V. Sáez** Grupo de Nuevos Desarrollos Tecnológicos en Electroquímica: Sonoelectroquímica y Bioelectroquímica, Grupo de Fotoquímica y Electroquímica de semiconductores, Departamento de Química Física e Instituto de Electroquímica, Universidad de Alicante, Alicante, Spain

**Jesús Sánchez-Martín** Department of Chemical Engineering and Physical Chemistry, University of Extremadura, Badajoz, Spain

**Rashmi Sanghi** Indian Institute of Technology Kanpur, UP, India

**Sanjay K. Sharma** Jaipur Engineering College & Research Centre, JECRC Foundation, Jaipur, India

**Vandana Singh** University of Allahabad, Allahabad, India

**Thammanoon Sreethawong** Baan Klangmuang Luzern, Suanluang, Bangkok, Thailand

**Jinsheng Sun** School of Chemical Engineering and Technology, Tianjin University, Tianjin, People's Republic of China

**Tjoon Tow Teng** School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia

**Chedly Tizaoui** Centre for Water Advanced Technologies and Environmental Research (CWATER), College of Engineering, Swansea University, Swansea, United Kingdom

**I. Tudela** Grupo de Nuevos Desarrollos Tecnológicos en Electroquímica: Sonoelectroquímica y Bioelectroquímica, Departamento de Química Física e Instituto de Electroquímica, Universidad de Alicante, Alicante, Spain

**Alexander L.N. van Nuijs** Toxicological Centre, University of Antwerp, Antwerp, Belgium

## About the Editors



**Prof. (Dr.) Sanjay K. Sharma** is a very well known author and Editor of many books, research journals and hundreds of articles from last 20 years. His recently published books are *Green Corrosion Chemistry and Engineering* (From Wiley-VCH, Germany), *Green Chemistry for Environmental Sustainability*, *Handbook on Applications of Ultrasound: Sonochemistry and Sustainability* (both from CRC Taylor & Francis Group, LLC, Florida, Boca Raton, USA) and *Handbook of Applied Biopolymer Technology: Synthesis, Degradation and Applications* (From Royal Society of Chemistry, UK). He has also been

appointed as Series Editor by Springer UK for their prestigious book series *Green Chemistry for Sustainability*. His work in the field of Green Corrosion Inhibitors is very well recognized and praised by the international research community. Other than this, he is known as a person who is dedicated to educate people about environmental awareness, especially for Rain Water Harvesting.

Dr. Sharma has 13 books of Chemistry from National-International Publishers and over 48 research papers of National and International repute to his credit. Dr. Sharma is also serving as Editor-in-Chief for four international research journals *RASAYAN Journal of Chemistry*, *International Journal of Chemical, Environmental and Pharmaceutical Research*, *International Journal of Water Treatment and Green Chemistry* and *Water: Research and Development*. He is also a reviewer for many other international journals including the prestigious *Green Chemistry Letters and Reviews*.

Presently he is working as Professor of Chemistry at Jaipur Engineering College and Research Centre, JECRC Foundation, Jaipur (Rajasthan) India, where he is teaching Engineering Chemistry and Environmental Engineering Courses to B. Tech. students, Spectroscopy courses to PG students and pursuing his research interests. He is a member of American Chemical Society (USA), International

Society for Environmental Information Sciences (ISEIS, Canada) and Green Chemistry Network (Royal Society of Chemists, UK) and is also life member of various international professional societies including International Society of Analytical Scientists, Indian Council of Chemists, International Congress of Chemistry and Environment, Indian Chemical Society, etc.

**E-mail: drsanjay1973@gmail.com**



**Dr. Rashmi Sanghi** is currently working as a Research Consultant at the Indian Institute of Technology Kanpur and guest faculty at the LNM Institute of Information Technology, Jaipur. After obtaining her D.Phil degree from Chemistry Department, University of Allahabad, India, in 1994, she has been working at the Indian Institute of Technology Kanpur, India, as a Research Scientist. She was a Visiting Scientist at Chemistry Department, Rutgers University, Piscataway, NJ, USA in 1997 and worked with Prof. Alan S. Goldman.

She is passionate about environmental green chemistry and her major research interests are bioremediation, biopolymers and biosynthesis of nanomaterials using microbes and/or polysaccharides. Her research mainly focuses on the development of methods that can help in minimizing or eliminating the hazardous substances in the environment. Some of this work related to the green environmental chemistry is nothing but outstanding. She has traveled worldwide for various academic activities and/or professional talks. Her work on design and application of biopolymers in wastewater remediation shows great promise as evident by her patents *A method for preparing auto capped nano particles such as CdS in continuous flow columns using fungus and Poly(acryl amide) grafted Cassia grandis-silica hybrid: efficient metal ion adsorbent*. She has over 90 international journal publications to her credit. She has published three books on green chemistry: *Green Chemistry: Environment Friendly Alternatives* (2003), *Green Chemistry and Sustainable Development* (2005) and *Green Chemistry for Environmental Remediation* (2011). She is a member of many academic societies and reviewer of many international journals.

**E-mail: rsanghi@iitk.ac.in; rsanghi@gmail.com**

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# Chapter 1

## Green Practices to Save Our Precious “Water Resource”

Sanjay K. Sharma, Rashmi Sanghi, and Ackmez Mudhoo

*Water is H<sub>2</sub>O, hydrogen two parts, oxygen one but there is also a third thing, that makes it water and nobody knows what that is.*

—D.H. Lawrence (1885–1930)

### 1.1 Introduction

Water is one of the world’s most precious resources without which life is not possible on Earth. It is equally important for agriculture and industry. We cannot imagine any “crop” or any “product” without the involvement of water. Apart from its necessity for life, it has many unusual properties. Water is the only element known to man that exists naturally in all three states of matter. For example, it has exceptional ability to store heat and can modify the earth’s temperature. In its solid form as ice, it has the ability to float on water allowing aquatic life to survive in winter. Water has a very significant role in chemistry as an excellent solvent that can dissolve many ionic and polar substances. That is why it is an effective medium for carrying nutrients to plants as well as to animals. Water in its liquid state can be classed as “strange” and “eccentric.”

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S.K. Sharma (✉)

Jaipur Engineering College & Research Centre, JECRC Foundation, Jaipur, India  
e-mail: drsanjay1973@gmail.com

R. Sanghi

Indian Institute of Technology Kanpur, UP 208016, India  
e-mail: rsanghi@gmail.com; rsanghi@iitk.ac.in

A. Mudhoo

Department of Chemical and Environmental Engineering, Faculty of Engineering,  
University of Mauritius, Mauritius  
e-mail: ackmezchem@yahoo.co.uk; a.mudhoo@uom.ac.mu