ENVIRONMENTAL NANOTECHNOLOGY
Applications and Impacts of Nanomaterials

Mark R. Wiesner • Jean-Yves Bottero
Contents

About the Contributors vii

Part I Nanotechnology as a Tool for Sustainability

Chapter 1. Nanotechnology and the Environment
Mark R. Wiesner and Jean-Yves Bottero 3

Nano-convergence and Environmental Engineering 4
Origin and Organization of this Book 6
References 13

Chapter 2. Nanotechnology and Our Energy Challenge
Wade Adams and Amy Myers Jaffe 15

Nanotechnology and Renewable Energy 19
Smalley Electricity Vision 22
Conclusion 24
References 25

Part II Principles and Methods

Chapter 3. Nanomaterials Fabrication
Jean-Pierre Jolivet and Andrew R. Barron 29

Specificity and Requirements in the Fabrication Methods of Nanoparticles 30
Oxides 31
Semiconductor Nanoparticles 58
(Quantum Dots and Quantum Rods)
Metallics, Bimetals, and Alloys 65
Carbon Based Nanomaterials 77
References 97

Chapter 4. Methods for Structural and Chemical Characterization
of Nanomaterials  Jérôme Rose, Antoine Thill, and Jonathan Brant 105

Introduction 105
Principles of Light-Material Interactions 106
Atomic Force Microscopy and Scanning Tunnel Microscopy
Structural Characterization 107
Surface Physico-Chemical Properties
References

Chapter 5. Reactive Oxygen Species Generation on Nanoparticulate Material
   Michael Hoffmann, Ernest M. Hotze, and Mark R. Wiesner

   Background
   Nanoparticulate Semiconductor Particles and ROS Generation
   Metal Sulfide Surface Chemistry and Free Radical Generation
   Fullerene Photochemistry and ROS Generation Potential
   References

Chapter 6. Principles and Procedures to Assess Nanomaterial Toxicity
   Michael Kovochich, Tian Xia, Jimmy Xu, Joanne I. Yeh,
   and André E. Nel

   Introduction
   Paradigms for Assessing NM Toxicity
   Overall Considerations in the Assessment of NM Toxicity
   Use of Cellular Assays to Study Other Responses that Are Relevant
to NM Toxicity, Including Cellular Uptake and Subcellular Localization
   Nanosensors: Sensitive Probes for the Biodetection of ROS
   Nanoelectrodes
   Online Data Bank
   Abbreviations
   Acknowledgements
   References

Chapter 7. Nanoparticle Transport, Aggregation, and Deposition
   Jonathan Brant, Jérôme Labille, Jean-Yves Bottero,
   and Mark R. Wiesner

   Introduction
   Physico-chemical Interactions
   Aggregation
   Deposition
   Nanoparticle Behavior in Heterogeneous Systems
   Airborne Nanoparticles
   Summary
   References

Part III Environmental Applications of Nanomaterials

Chapter 8. Nanomaterials for Groundwater Remediation
   Gregory V. Lowry

   Introduction
   Reactivity, Fate, and Lifetime
   Delivery and Transport Issues
   Targeting
   Summary and Research Needs
   List of Acronyms and Symbols
   References
Chapter 9 Membrane Processes  *Mark R. Wiesner, Andrew R. Barron, and Jérôme Rose*  
Overview of Membrane Processes  337  
Transport Principles for Membrane Processes  338  
Membrane Fabrication Using Nanomaterials  341  
Nanoparticle Membrane Reactors  356  
Active Membrane Systems  366  
References  367

Chapter 10 Nanomaterials as Adsorbants *Mélanie Auffan, Heather J. Shipley, SuJin Yean, Amy T. Kan, Mason Tomson, Jérôme Rose, and Jean-Yves Bottero*  
Introduction  371  
Adsorption at the Oxide Nanoparticles/Solution Interface  372  
Nanomaterial-Based Adsorbents for Water and Wastewater Treatment  377  
Concluding Remarks  388  
Acknowledgements  389  
References  389

Part IV Potential Impacts of Nanomaterials

Chapter 11. Toxicological Impacts of Nanomaterials *Nancy A. Monteiro-Riviere and Thierry Orsière*  
Introduction  395  
Fullerenes  396  
Single-Walled Carbon Nanotubes (SWCNT)  401  
Multi-Walled Carbon Nanotubes (MWCNT)  403  
Complications in Screening Assays Using Carbon-Based Materials  405  
Titanium Dioxides  406  
Iron Oxides  412  
Cerium Dioxides  420  
Copper Nanoparticles  421  
Gold Nanoparticles  422  
Quantum Dots  424  
Exposure and Risk Assessment  431  
Environmental Impact  433  
Conclusion  434  
References  434

Chapter 12. Ecotoxicological Impacts of Nanomaterials *Delina Y. Lyon, Antoine Thill, Jérôme Rose, and Pedro J.J. Alvarez*  
Introduction  445  
Why Study the Effects of Nanomaterials on Microorganisms?  447  
Methods to Assess Ecotoxicity  448  
Bioavailability and Cellular Uptake of Nanoparticles  452  
Nanomaterial Interaction with Microbial Cell Components  456  
Antibacterial Activity of Nanomaterials  459  
Biotransformation of Nanomaterials by Microbes  466
Acknowledgments

Portions of the work presented in this book were supported by grants from the US National Science Foundation, the US Environmental Protection Agency, and the ECCO-Dyn program of France’s CNRS-FNS. Support from the Office of Science and Technology of the French Consulate (Houston), and Rice’s Environmental and Energy Systems Institute in organizing the symposia that led to this effort are also gratefully acknowledged.
This review outlines the latest advances in nanomaterials, nanostructures, nanotechnologies and their environmental impact. Environmental restoration is based on the use of physic-chemical methods: adsorption, absorption, chemical reactions, photocatalysis, filtration and technologies that remove contaminants from soil, water and air. New technologies and nanomaterials are now being developed for environmental restoration. Environmental Nanotechnology, Monitoring and Management is a journal devoted to the publication of peer reviewed original research on environmental nanotechnologies, monitoring studies and management for water, soil, waste and human health samples. Critical review articles, short communications and scientific policy briefs are also welcome. The journal will include all environmental matrices except air. Nanotechnology Applications for Measurement in the Environment. Nanotechnology Applications for Sustainable Materials and Resources. This report on nanotechnology and the environment is one of a series of reports resulting from topical workshops convened during 2003 and 2004 by the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the National Science and Technology Council’s Committee on Technology through the National Nanotechnology Coordination Office (NNCO). The Environmental Nanotechnology section publishes high-quality research on the application of nanoscience and nanotechnology to reducing or preventing damage to the environment. It presents cutting-edge remediation technologies and advanced nanomaterials for sustainability, as well as the sustainable design, development and use of nanotechnologies and nanomaterials. Read More. Your research can change the world. How will nanotechnology affect our lives - this part will not look in terms of the technological impact such as faster and cheaper computers, but at the very important health and environmental effects that necessarily must be considered. When will it help cure cancer or and when might it cause it? Will the apparent ecological benefit of a nanoparticle that improves catalytic reactions be futile when we consider the ecological footprint of the nanoparticles’ life cycle? There are many open questions.