Frontiers of Nanoscience
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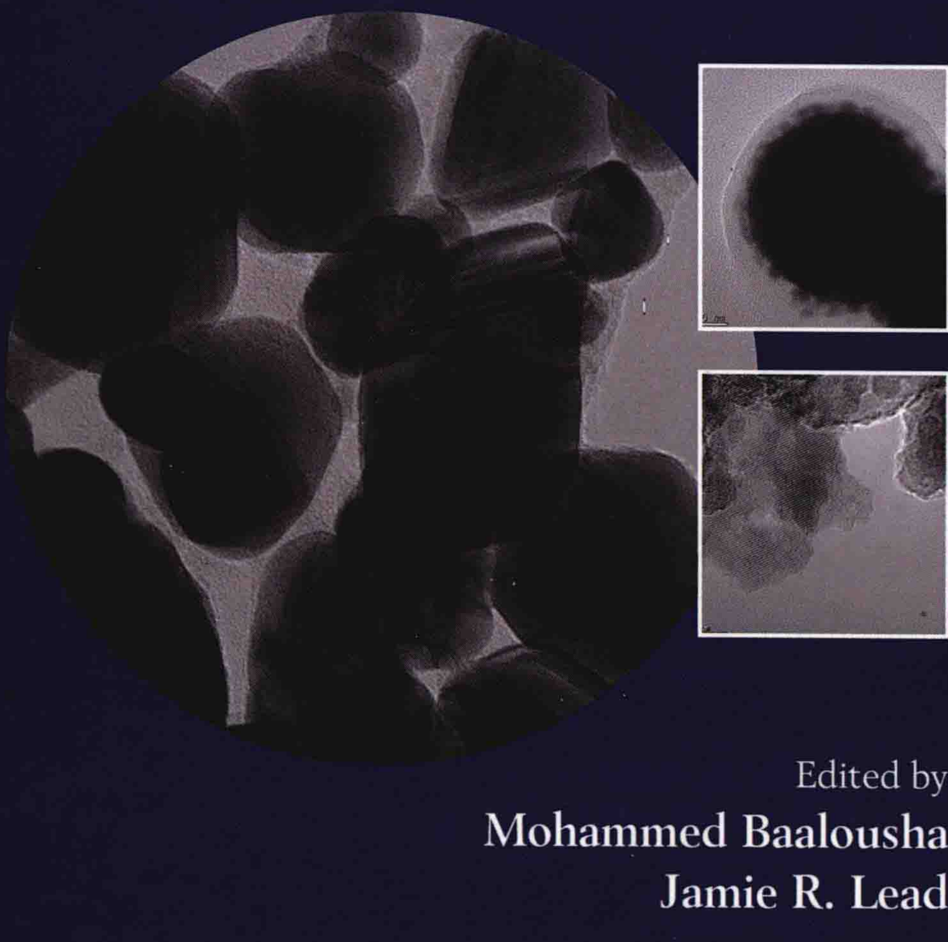
Volume 8

Characterization of Nanomaterials in Complex Environmental and Biological Media



Edited by
Mohammed Baalousha
Jamie R. Lead

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Characterization of Nanomaterials in Complex Environmental and Biological Media

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Preface

In spite of a decade of research in determining the fate, behavior and biological impact of nanomaterials, the precise role of their properties in these processes is still poorly understood. This is due to the multidisciplinary nature of the problem in hand requiring experts in material science, chemistry, physics, biology and toxicology to be brought together. In addition, the complexity of nanomaterial properties, behaviours and dynamic transformations in environmental and biological media makes the problem extremely challenging. The problem is further exacerbated by the lack of nanomaterial characterization methods for complex media, standard sample-preparation methods, technical expertise and understanding and interpretation of the measured parameters. As a result, there are significant discrepancies between measurements performed on different nanomaterial batches by different analytical techniques and among different research groups. Despite the significant progress in the quality of material characterization over the last few years, the majority of research papers describing environmental and toxicological behaviours of nanomaterials do not fully address nanomaterial characterization, and put little emphasis on linking nanomaterial properties to their environmental behaviours. As a result, there are huge discrepancies in the available literature regarding, for instance, the role of size, particles and ions, surface coatings, etc. Therefore, this book was written in part as a survey of the state of the art in nanomaterial characterization for experts as well as for those investigating the fate and effects of nanomaterials. In part, it is also an effort to bridge this knowledge gap and to better understand nanomaterial characterization and the role of nanomaterial properties in controlling their environmental and toxicological behaviour.

The book was organized to accommodate the vision outlined above by summarizing the current state of the art in nanomaterial characterization, with a focus on modern and novel application of techniques that have not been previously examined in detail or techniques that have seen vast methodological improvements in recent years. The book is divided into three parts; **the first part** (Chapters 1 and 2) reviews the current state of the art of nanomaterial toxicity to aquatic organisms and nanomaterial characterization techniques; **the second part** (Chapters 3–7) carefully and critically describes characterization of specific properties of nanomaterials relevant to their environmental behaviours applying a multi-method approach, with specific attention to sample preparation and comparability of measurements performed by different analytical techniques and **the third part** (Chapters 8 and 9) presents two case studies of nanomaterial characterization in consumer products and food stuffs.

More specifically, **Chapter 1** gives a critical review on current nanomaterial toxicity data in aquatic organisms, nanomaterial dose-metric and nanomaterial features that elicit toxicity, the importance of nanomaterial characterization in underpinning nanomaterial health and safety research. **Chapter 2** provides the reader with an overview of the basic concepts of the plethora analytical techniques that can be applied to measure nanomaterial properties of relevance to their environmental behaviour, fate and effects.

Chapter 3 gives an account of nanomaterial size characterization based on microscopy techniques, diffusion coefficient and other advanced approaches such as single particle inductively coupled plasma–mass spectrometry. This chapter presents the general consideration for size analysis, the descriptors of size distributions, the comparison and interconversion between distributions and ends with a discussion of the general considerations for nanomaterial size characterization in environmental systems. **Chapter 4** discusses how to identify and characterize chemical composition and crystal structure (and therefore the exact phase or phases) of nanomaterials (parent forms) as well as their transformed ones (daughter forms) by using analytical transmission electron microscopy and scanning transmission electron microscopy. This chapter gives special attention to data acquisition and analysis methods, as well as sample-preparation procedures in great detail. **Chapter 5** examines the characterization of the three most commonly measured particle concentration metrics, namely mass, surface area and number. The chapter discusses the methods used to measure these metrics, and sample preparation for selected methods, including microscopy and inductively coupled plasma–mass spectrometry. Available analytical techniques for mass, surface area and number concentration measurements are systematically evaluated in terms of sensitivity/detection range for nanomaterial mass, representing nanomaterial surfaces in dispersion, distinguishing nanomaterials in complex medium and minimizing sampling artefacts in number distributions. **Chapter 6** highlights the complex interrelationship between: the form of a nanoparticulate material dispersed in a particular medium; the resultant dissolution or chemical change of the nanomaterials in that delivery medium and the nature and degree of uptake of the nanomaterials by a particular cell or organism. Thus, the chapter reviews the various techniques which are appropriate to determine nanomaterial dispersion, dissolution and dose. **Chapter 7** discusses the importance of nanomaterial surface properties and surface reactions such as surface area, surface atomic arrangements, and adsorption, photocatalytic and redox reactions. This is followed by describing a multi-method approach for the characterization of nanomaterial surface properties and reactions, with special attention given to sample preparation to preserve surface properties. The chapter intentionally distinguishes between surface-specific and non-surface-specific techniques.

Chapter 8 presents a case study on the characterization of common chemical mechanical polishing/planarization nanomaterials such as silica, cerium and aluminium oxides. The chapter investigates nanomaterial removal efficiency using a common industrial on-site treatment strategy (chemical softening and precipitation) and off-site treatment at biological wastewater treatment plants. **Chapter 9** focuses on the characterization of nanomaterials in foodstuffs and food contact materials, and covers approaches for sample preparation prior to analysis; the analytical techniques available for nanomaterial detection and characterization in food matrices and the appropriateness of various QA and QC methodologies. The chapter ends by discussing the specific challenges associated with nanomaterial detection, with analysis in food, beverages and nutraceuticals also discussed.

As the reader will appreciate, due to the breadth of the topic and the skills needed to put this book together, this book would not have been realized without the contributions of the authors of each chapter. Accordingly, we would like to express our gratitude to all authors who have contributed to this work and recognize the efforts that made this publication possible. We would like also to thank various funding bodies supporting the editors in their general research that led the editors to develop this book, in particular, the U.S. National Science Foundation, the Center for Environmental Nanoscience and Risk and the Arnold School of Public Health at the University of South Carolina. Lastly, we would like to thank the publishing team at Elsevier whose help was vital for this book.

Mohammed Baalousha and
Jamie R. Lead

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