Nanotechnologies for the Life Sciences

Edited by Challa Kumar

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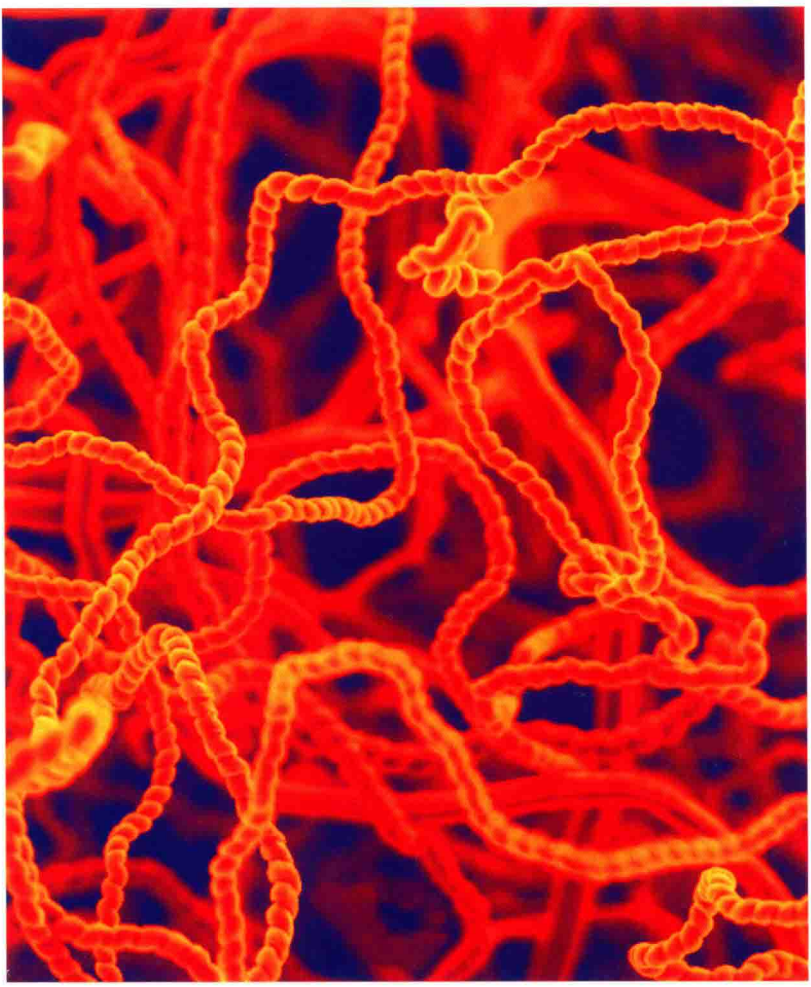
Nanomaterials – Toxicity, Health and Environmental Issues



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Volume 5

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Preface

It is my pleasure to welcome the readers back to *Nanotechnologies for the Life Sciences* with the first volume published in 2006. I am presenting to you, on behalf of yet another dedicated team of contributors and supporters, the fifth volume, *Nanomaterials – Toxicity, Health and Environmental Issues*, of the ten volume series. We are bringing the fifth volume while the fourth is still in print for a number of reasons. The most important being the fact that a potential $1 trillion nanotechnology market hinges on understanding the toxic effects of nanomaterials on our health and environment. With continuous world-wide increase in both government and private funding in nanoscience and nanotechnology touching close to $35 billion, the stakes are even higher. With increase in stakes, there is a worldwide awakening to understand the toxic effect of nanomaterials and the scholarly chapters presented in this book are testimony to the efforts of several research groups to understand these effects. While the current knowledge base is small compared to what needs to be understood, it certainly provides a scaffold for this knowledge base to take definite shape.

Some of the critical risk assessment issues that are currently being investigated by the health & environmental nano researchers are toxicology, exposure assessment, environmental and biological fate, transport, persistence, transformation, recyclables and overall sustainability of manufactured nanomaterials. I am aware that the scientific data generated so far is very scanty and requires more worldwide concerted effort in this direction. Nevertheless, the amount of information presented by the authors covers almost everything of what is currently available in the literature. The book is divided into three distinct sections in an attempt to emphasize the three major issues related to nanomaterials, which are toxicology, health and environment. The boundaries are only artificial and have been created for the sake of clarity. I am aware that the three issues are interrelated, yet unique in their own way. I am also aware the field is very nascent and hence there could be some amount of overlap in terms of information that is presented in the chapters. However, the USP of the book is that all the chapters provide very unique and intellectually stimulating perspectives on the most important topics in the field of nanoscience and nanotechnology.

The first section of the book deals, in general, with issues around the toxicity of nanomaterials and begins with a scholarly report on the toxic effects of metal oxide

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nanoparticles which are by far, commercially, the most significant materials as they find applications in cosmetics, sunscreens, fillers in dental materials, water filtration processes, catalysis, glare-reducing coating for glasses, and so on. Amanda M. Fond and Gerald J. Meyer from the Department of Chemistry, Johns Hopkins University, USA have reviewed the literature, in addition to capturing their own findings, on biotoxicity of metal oxide nanoparticles keeping the emphasis more on *in vitro* rather than *in vivo* studies. In this chapter entitled, *Biotoxicity of Metal Oxide Nanoparticles*, their critical analysis provides to the reader possible mechanisms by which the metal oxide nanoparticles enter the environment and the body, and the potential health impacts that might be expected. Eva Oberdörster from Southern Methodist University, Patricia McClellan-Green from NC State University and Mary Haasch from University of Mississippi have collaborated to present their critical evaluation in the second chapter, *Ecotoxicity of Engineered Nanomaterials*, impact of nanomaterials on the environment, and more specifically on air, water and soil. In addition, readers will find very useful the authors' insight into how the activity of nanomaterials is effected by extraneous factors such as abiotic factors, microbial degradation/activation and identification of biomarkers associated with nanoparticle exposure.

In the second section of the book, illuminating perspectives on the effect of nanomaterials on health are presented. Relative to the increased use of nanomaterials in a variety of industrial applications, the amount of information regarding their health effects is limited. Peter Hoet from Katholieke Universiteit Leuven, Belgium, Irene Brüske-Hohlfeld from GSF-Forschungszentrum für Umwelt und Gesundheit, Germany, and Oleg V. Salata from Sir William Dunn School of Pathology, University of Oxford, UK, teamed up in order to review the epidemiological studies of the technogenic nanoparticles and to highlight the apparent health effects associated with the inhalation of ultrafine particulate matter. The third chapter by them, aptly entitled *Possible Health Impact of Nanomaterials*, provides information on likely pathways for nanoparticulates in general and nanofibers in particular inside the body, the effects associated with their interactions on the cellular level, and analysis of the origins of bioactivity of nanomaterials. Continuing on the same theme, chapter number four, *Dosimetry, Epidemiology and Toxicology of Nanoparticles*, describes the dosimetry, epidemiology and toxicology of nanoparticles with reference to generally well established principles and paradigms. The chapter is contributed by Wolfgang G. Kreyling, Manuela Semmler and Winfried Möller from GSF-National Research Centre for Environment & Health, Institute for Inhalation Biology, Focus-Network Aerosols and Health, and Clinical Research Group 'Inflammatory Lung Diseases' respectively, from Germany. The highlight of the chapter, in my view, is described best by the authors themselves: "extrapolating findings and principles observed in particle inhalation toxicology into recommendations for an integrated concept of risk assessment of nanoparticles for a broad range of use in science, technology and medicine." Focusing more specifically on ceramic and metallic nanoparticles, the team lead by Kirsten Peters from Institute of Pathology, Johannes Gutenberg University, Germany, discusses in chapter five their effects on primary human endothelial cells which are highly relevant for

nanoparticle transmigration from the blood into tissues. The chapter, *Impact of Ceramic and Metallic Nano-Scaled Particles on Endothelial Cell Functions in vitro*, clearly helps readers to understand, with an example of pro-inflammatory stimulation of endothelial cells by nanoparticles, that even though it is clear that the nanoparticles exert effects that are relevant in vitro, these cannot be easily interpreted and may not be of relevance in vivo. The sixth chapter, *Toxicity of Carbon Nanotubes and its Implications for Occupational and Environmental Health*, written by the team lead by Chiu-Wing Lam from the Division of Space Life Sciences, NASA Johnson Space Center, and Wyle Laboratories, Houston, USA, is a comprehensive review on the toxicological risk of carbon nanotubes (CNT) and the impurities present in them due to inhalation exposures using both rodent and in vitro cell culture studies. In addition, the authors discuss the mechanisms of CNT pathogenesis in the lung and other toxicological manifestations. In view of the growing expectations that CNTs will find extraordinary applications in the field of not only life sciences but also in electronics, computer, and aerospace industries, the chapter is timely and will be a single source of information for the readers. The final chapter in this section is the seventh chapter, wherein the authors review the latest results from various studies on the biological effects of nanoparticles that may be the basis for adverse effects, especially in humans. The chapter, *Toxicity of Nanomaterials – New Carbon Conformations and Metal Oxides*, provides a comparative study on two most important classes of nanomaterials, viz carbon and metal oxide based nanomaterials, with respect to their cellular uptake and possible influence on important cellular mechanisms in vitro. The chapter is a testimony to the intensive analysis on the topic carried out by the authors Harald F. Krug, Katrin Kern, Jörg M. Wörle-Knirsch, and Silvia Diabate from the Institute of Toxicology and Genetics at Forschungszentrum Karlsruhe, Germany.

The final section and the most important one, in my view, is dedicated to the investigations related to impact of nanomaterials on environment. While the chapters 1–7 in the previous sections dealt with possible negative effects of nanomaterials, this sections portrays the positive aspects of nanomaterials. The first chapter in this section (8th in the book) is contributed by Glen E. Fryxell and Shas V. Mattigod of Materials Chemistry and Surface Research Group, Pacific Northwest National Laboratory, USA. In this chapter, *Nanomaterials for Environmental Remediation*, the authors address one of the key global political and economic issues of the 21st century – how does one ensure that the majority of the world population has clean environment in general and air & water in particular in future? An analysis of nanoparticle-based remediation technologies for air and water treatment including field tests on actual waste streams is presented. Moving into the ninth chapter, readers will find more specific information regarding the variety of approaches being utilized for treatment of water with nanomaterials. In this chapter, entitled *Nanomaterials for Water Treatment*, Peter Majewski of Ian Wark Research Institute, University of South Australia, Australia, is upbeat about various technologies currently under development and more specifically about the approach using magnetic iron exchange resin (MIEX) which is already commercially applied in water treatment. It is heartening to read the next chapter, chapter ten, wherein

Heather Coleman from the Centre for Particle and Catalyst Technologies of the University of New South Wales, Sydney, Australia, elaborates on how nanotechnologies are proving to be playing a major role in alleviating the concerns about the release into the aquatic environment of natural and synthetic oestrogens and compounds that have the ability to mimic oestrogens. In this chapter, *Nanoparticles for the Photocatalytic Removal of Endocrine Disrupting Chemicals in Water*, the author describes nanoscale titanium dioxide photocatalysis for the degradation of the natural and synthetic oestrogens in water. Chapter eleven by Wan Y. Shih and Wei-Heng Shih, Department of Materials Science and Engineering, Drexel University, Philadelphia, USA, is very unique in the sense that the authors describe their own investigations into the development of piezoelectric microcantilever sensors of different sizes and types that can perform rapid, in-situ, in-water pathogen detection with sensitivities well above that of the current techniques. The chapter describes both theoretical and experimental studies that were carried out to characterize the sensors. While the information provided in the chapter, *Nanosensors for Environmental Applications*, clearly demonstrates that we have a long way to go before realizing the dream of fabricating truly nanosize sensors, it is hoped that the chapter will form a strong basis for readers in designing their own nanosensors for environmental applications. The final chapter, *Toxicology of Nanoparticles in Environmental Air Pollution* by Ken Donaldson and his collaborators, puts forward the evidence that nano-sized air pollutants play adverse role on our health. I confess that this chapter could have been included in the previous section. However, since the chapter describes nanosized partriculate matter present in the natural environment, I have decided to include it in this section. As a final chapter, I also wanted the reader to take home the message that while certainly nanomaterials can be utilized to clean up our environment and treat variety of diseases, one needs to be aware of the deleterious effects of nano-sized particulate matter in the environment.

In the end, I would like to state that I am indeed very grateful to all the authors for their contribution of quality manuscripts on time. I am thankful to my employer, family, friends and Wiley-VCH publishers for making this book a reality. I am always indebted to you, the reader, who is an integral part of this journey into brining nanotechnologies to life sciences and life sciences into nanotechnologies. I am eagerly waiting to receive your comments, suggestions and constructive criticism to make this journey even more enjoyable and a learning experience for all.

March 2006, Baton Rouge *Challa S. S. R. Kumar*

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