Editors Jamie R. Lead and Emma Smith

Environmental and Human Health Impacts of Nanotechnology

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Preface

Manufactured nanoparticles (NPs) are usually defined as materials purposefully produced by human activity and which have at least one dimension between 1 and 100 nm. It is important to distinguish NPs by source; the main other NPs are incidental: that is produced indirectly by human activities including fossil fuel combustion, and natural: that is produced by processes such as chemical hydrolysis, weathering and microbial action. Other size-based definitions of NPs exist and there are a wide variety of material types which fall within this definition. Nanoscience, which is the science dealing with nanoscale materials, can be seen as simply a subset of traditional colloids science. Nevertheless, a large number of novel processes occur below this size due to effects such as exponential increases in specific surface area and surface energy, quantum effects such as quantum confinement (where wave functions are constrained by the small particle size) and under-coordination of bonds at the particle surface. Processes which occur in this size range are thus different in many ways to traditional colloid chemistry and, in general, the differences become more pronounced at smaller sizes.

The current interest in nanotechnology is due to these novel properties and their exploitation in industrial processes and consumer products. Huge and exponentially growing research and development funding from government and private sources has been spent to better develop and exploit these potential uses and NPs are now used widely. Silver NPs are currently used as bacteriocides in cosmetics, fabrics, medical and health-related products and elsewhere. Titanium dioxide NPs are used in sunscreens (along with zinc oxide) and self cleaning surfaces, where they have a photocatalytic effect on organic matter due to the production of reactive oxygen species (ROS) and because of this titania is also used as a bacteriocide. Cerium dioxide is widely used as an additive to diesel to improve fuel efficiency. A wide range of other materials such as carbon nanotubes, fullerenes, gold, iron, iron oxide and more exotic species are being developed and used.

The extent of the applications and the possibility of unusual and unknown 'nano' effects has led to concern about their environmental and human health effects in the scientific community and equal concern in industry and from regulators and policy makers. A major driver for this in some quarters is undoubtedly the example of genetically modified organisms. The extensive public backlash has made the future of that technology quite uncertain and there has been a different approach in nanotechnology to openness and acknowledgement of the risks and a commitment to reducing these risks. Public response to nanoscience and nanotechnology is currently limited by a lack of knowledge and wider impact but is generally positive with benefits expected in health, energy and the environment to name a few. Nevertheless, it is quite feasible that this attitude will change, particularly in view of developments in next generation nanomaterials, including self-organisation and self-assembly and the increasingly researched interface between 'bio' and 'nano'.

There are considerable benefits to be gained from the exploitation of nanoscience but current research tells us that there are indeed potential hazards in this area. It is incumbent on the relevant communities to ensure that NPs and other nanomaterials are used appropriately and designed and tested to be of minimal hazard and that exposure is not widespread; risk needs to be minimised and seen to be minimised to allow the full benefits of nanoscience and nanotechnology to be derived.

Understanding the behaviour and impacts of nanotechnology in the environment and in human health is a daunting task and many questions remain to be answered: how do we measure concentrations of NPs in complex biological and environmental media?; what are the concentrations in environmental media and in organisms?; what are the correct metrics of measurement (mass or number concentrations for instance)?; what are the sources to the environment and humans?; what are the environmental transport pathways and ultimate sinks of NPs?; are NPs bioavailable and are they subject to bioaccumulation and biomagnification?; how do NPs distribute in the sub-cellular, organ and body environments?; how are transport, bioavailability and effects related to NP physico-chemical structure? Although a substantial amount of research is being performed, the research spending on the risks of nanotechnology and the health and safety and environmental implications is still tiny in comparison to its development and exploitation. This balance is unlikely to change enormously but there are good arguments to say that this should happen and change should come quickly. The questions above and related questions remain unanswered in the main and the purpose of this volume is to collate and discuss our current knowledge and point to future areas of research which are required.

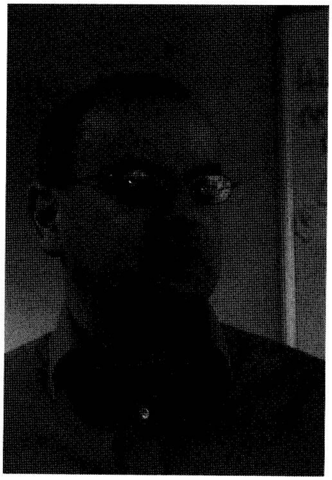
We would like to acknowledge and thank a number of people and institutions which made this book possible. The UK Natural Environment Research Council (NERC) provided funding via a Knowledge Transfer Network entitled Engineered nanoparticles in the natural aquatic environment (Nanonet), which enabled all authors and editors to convene for a two-day workshop to discuss the issues and finalise the chapters. We would like to thank the chapter authors for their efforts and their timely submissions, and the patience and help of the publishing team which was essential to the editors.

Jamie Lead

Emma Smith

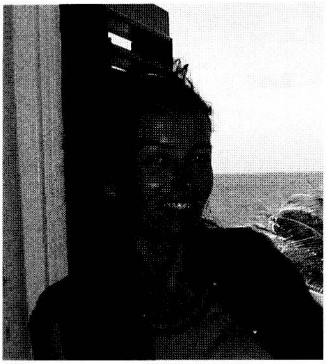
March 2009

Biographies



Jamie Lead is Professor of Environmental Nanoscience in the School of Geography, Earth and Environmental Sciences, University of Birmingham, UK. Professor Lead completed his PhD at Lancaster University, UK, in 1994 after investigating lanthanide and actinide speciation in natural waters and soils. At the same institution he later undertook postdoctoral research on the impact of size of natural aquatic colloids on transition metal chemistry. In 1998, he undertook further postdoctoral work at Geneva University, Switzerland, developing and using fluorescence correlation spectroscopy to quantify diffusion coefficients of natural organic macromolecules. In 2000, he became a Lecturer at the University of Birmingham and became full Professor at Birmingham in 2008. Professor Lead is Director of the Facility for Environmental Nanoparticle Analysis and Characterisation (FENAC), which is a national UK centre collaborating with the biological community investigating nanoparticle fate and effects. He has been a visiting researcher at CSIRO, Australia, and is a Fellow of the Royal Society of Chemistry, the International Union of Pure and Applied Chemistry and the Institute of Nanotechnology.

Professor Lead's main research interests, where he has published widely, relate to the relationships between chemistry, transport and bio-uptake of pollutants, especially in relation to the nanoscale in the environment. In particular, he is interested in the structure of natural 'nanocolloids' and the role this has in metal and manufactured nanoparticle chemistry, fate and behaviour. He is currently collaborating extensively with the ecotoxicological community by synthesising nanoparticles of silver, cerium, iron oxide and other materials and ensuring their full characterisation. These collaborations are particularly focussed on investigating mechanisms of nanoparticle biological uptake and effects



Dr Emma Smith is currently Lecturer in Environmental Chemistry at the University of the West Indies. She received a degree in Oceanography and Chemistry from the University of Liverpool and a Masters in Marine Resource Development and Protection with distinction from Heriot Watt University. Her PhD thesis, Unresolved Complex Mixtures of Aromatic Hydrocarbons in the Marine Environment: Solubility, Toxicity and Photodegradation Studies, was carried out at Plymouth University in conjunction with Plymouth Marine Laboratory and won the SETAC Young Scientist Award in 2000 at World Congress in Brighton. Dr Smith then worked at Plymouth University on the characterisation of bioaccumulated and unidentified agent(s) causing reduced scope for growth in mussels and the potential ecological effects of chemically dispersed and biodegraded crude oils. She then worked at the University of Toronto within the Environmental NMR Centre, evaluating climatic controls on soil organic carbon composition and potential responses to global warming. Following this Dr Smith worked with Professor Lead at the University of Birmingham implementing the Nanonet project, a Knowledge Transfer (KT) Network in the area of manufactured nanomaterials (MNs) in the natural aquatic environment.

In her current position she is responsible for teaching environmental chemistry, oceanography and ecotoxicology at UWI and is working with the Caribbean Ecohealth Programme and an EU Outreach project on assessing the potential environmental and human health effects of pollution.

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