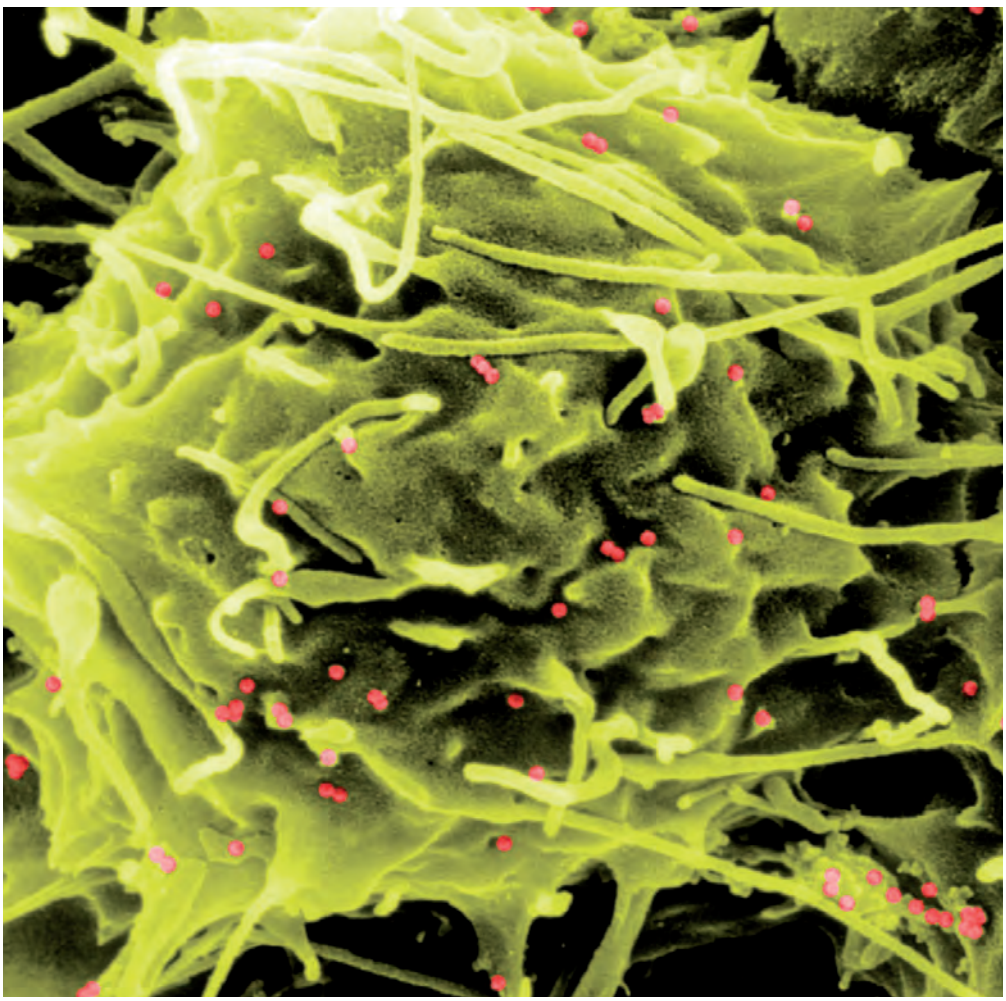
Issues in Environmental Science and Technology Vol 24

Edited by R E Hester and R M Harrison

Nanotechnology

Consequences for Human Health and the Environment



RSC Publishing

Nanotechnology
Consequences for Human Health and the Environment

ISSUES IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY

EDITORS:

EDITORIAL ADVISORY BOARD:

TITLES IN THE SERIES:

1. Mining and its Environmental Impact
2. Waste Incineration and the Environment
3. Waste Treatment and Disposal
4. Volatile Organic Compounds in the Atmosphere
5. Agricultural Chemicals and the Environment
6. Chlorinated Organic Micropollutants
7. Contaminated Land and its Reclamation
8. Air Quality Management
9. Risk Assessment and Risk Management
10. Air Pollution and Health
11. Environmental Impact of Power Generation
12. Endocrine Disrupting Chemicals
13. Chemistry in the Marine Environment
14. Causes and Environmental Implications of Increased UV-B Radiation
15. Food Safety and Food Quality
16. Assessment and Reclamation of Contaminated Land
17. Global Environmental Change
18. Environmental and Health Impact of Solid Waste Management Activities
19. Sustainability and Environmental Impact of Renewable Energy Sources
20. Transport and the Environment
21. Sustainability in Agriculture
22. Chemicals in the Environment: Assessing and Managing Risk
23. Alternatives to Animal Testing
24. Nanotechnology

How to obtain future titles on publication

A subscription is available for this series. This will bring delivery of each new volume immediately on publication and also provide you with online access to each title via the Internet. For further information visit http://www.rsc.org/Publishing/Books/issues or write to the address below.

For further information please contact:
Sales and Customer Care, Royal Society of Chemistry, Thomas Graham House, Science Park, Milton Road, Cambridge, CB4 0WF, UK
Telephone: +44 (0)1223 432360, Fax: +44 (0)1223 426017, Email: sales@rsc.org

ISSUES IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY

EDITORS: R.E. HESTER AND R.M. HARRISON

24
Nanotechnology: Consequences for Human Health and the Environment

RSC Publishing

ISBN-13: 978-0-85404-216-6
ISSN: 1350-7583

A catalogue record for this book is available from the British Library

Published by The Royal Society of Chemistry,
Thomas Graham House, Science Park, Milton Road,
Cambridge CB4 0WF, UK

Registered Charity Number 207890

For further information see our web site at www.rsc.org

Preface

Few outside of the world of science and technology have much concept of what nanotechnology involves. It is defined in terms of products and processes involving nanometre (*i.e.* 10^{-9} or 0.000 000 001 m) dimensions but this gives no flavour for what is truly involved. What may be surprising to many is that there is a massive thrust of research and development leading to new products involving nanoscale materials and it is projected that this will be a multi-billion dollar industry within a matter of a few years. Having in the past failed to anticipate the adverse public health consequences of products such as asbestos, governments around the world are investing resource into assessing the possible adverse consequences arising from the present and future application of nanotechnologies. This led the Royal Society and the Royal Academy of Engineering in the UK to publish an expert report on the topic under the title of ''Nanoscience and nanotechnologies: opportunities and uncertainties''. One manifestation of this government's concern is that in the UK a system has been introduced by the government for the voluntary notification of products and processes using nanoscale materials.

Some nanoscale materials such as carbon black, titanium dioxide and silica have been in high tonnage production in industry for many years, with a wide range of uses. However, a vast range of other nanoscale materials are now being produced with uses as diverse as manufacturing tennis balls which retain their bounce for longer and underwear with an antimicrobial coating. The concerns over nanoparticles and nanotubes relate to the observation that they are more toxic per unit mass than the same materials in larger particle forms. Whilst the evidence for extreme toxicity of the traditionally produced nanoscale materials is lacking, there remains concern that new forms of engineered nanomaterials may prove to be appreciably toxic. There is no doubt that by virtue of their size they have a much stronger ability to penetrate into the human body than more conventionally sized materials.

This volume of Issues seeks to give a broad overview of the sources, behaviour and risks associated with nanotechnology. In the first chapter, Barry Park of Oxonica Limited, a company specialising in nanoscale products, gives an overview of the current and future applications of nanotechnology. This is followed by a discussion of nanoparticles in the aquatic and terrestrial environment by Jamie Lead of the University of Birmingham, which includes consideration of the behaviour of nanoparticles both in the aquatic environment and within soils where they can be used in remediation processes. This is followed in a third chapter by Roy Harrison with a consideration of nanoparticles within the atmosphere. Currently, this is the most important medium for human exposure, although there is very limited evidence that nanoparticles play a particularly prominent role within the overall toxicity of airborne particulate matter.

Currently, those receiving the highest exposures to nanoparticles and nanotubes are those people occupationally exposed in the industry, and in the following chapter David Mark of the Health and Safety Laboratory describes the issues of occupational exposure, including how it can be assessed and currently available data from industrial sites. The following two chapters deal respectively with the toxicological properties and human health effects of nanoparticles. In the former chapter, Ken Donaldson and Vicki Stone give a toxicological perspective on the properties of nanoparticles and consider why nanoparticle form may confer an especially high level of toxicity. This is then put into context in the following chapter by Lang Tran and co-authors, which looks for hard evidence of adverse effects upon human health both in the occupational environment and in outside air.

This volume is rounded off by a chapter by Andrew Maynard, Chief Science Adviser to the Project on Emerging Nanotechnologies of the Woodrow Wilson International Center for Scholars in the United States, which highlights the problems of regulation that are presented by a burgeoning nanotechnology industry and gives some comfort in that the problems and solutions emerging in North America do not differ greatly from those being formulated within Europe.

Overall, the volume provides a comprehensive overview of the current issues concerning engineered nanoparticles which we believe will be of immediate value to scientists, engineers and policymakers within the field, as well as to students on advanced courses wishing to look closely into this topical subject.

Ronald E. Hester
Roy M. Harrison

Contents

Editors

Ronald E. Hester, BSc, DSc(London), PhD(Cornell), FRSC, CChem

Ronald E. Hester is now Emeritus Professor of Chemistry in the University of York. He was for short periods a research fellow in Cambridge and an assistant professor at Cornell before being appointed to a lectureship in chemistry in York in 1965. He was a full professor in York from 1983 to 2001. His more than 300 publications are mainly in the area of vibrational spectroscopy, latterly focusing on time-resolved studies of photoreaction intermediates and on biomolecular systems in solution. He is active in environmental chemistry and is a founder member and former chairman of the Environment Group of the Royal Society of Chemistry and editor of 'Industry and the Environment in Perspective' (RSC, 1983) and 'Understanding Our Environment' (RSC, 1986). As a member of the Council of the UK Science and Engineering Research Council and several of its sub-committees, panels and boards, he has been heavily involved in national science policy and administration. He was, from 1991 to 1993, a member of the UK Department of the Environment Advisory Committee on Hazardous Substances and from 1995 to 2000 was a member of the Publications and Information Board of the Royal Society of Chemistry.

Roy M. Harrison, BSc, PhD, DSc(Birmingham), FRSC, CChem, FRMetS, Hon MFPH, Hon FFOM

Roy M. Harrison is Queen Elizabeth II Birmingham Centenary Professor of Environmental Health in the University of Birmingham. He was previously Lecturer in Environmental Sciences at the University of Lancaster and Reader and Director of the Institute of Aerosol Science at the University of Essex. His more than 300 publications are mainly in the field of environmental chemistry, although his current work includes studies of human health impacts of atmospheric pollutants as well as research into the chemistry of

pollution phenomena. He is a past Chairman of the Environment Group of the Royal Society of Chemistry for whom he has edited 'Pollution: Causes, Effects and Control' (RSC, 1983; Fourth Edition, 2001) and 'Understanding our Environment: An Introduction to Environmental Chemistry and Pollution' (RSC, Third Edition, 1999). He has a close interest in scientific and policy aspects of air pollution, having been Chairman of the Department of Environment Quality of Urban Air Review Group and the DETR Atmospheric Particles Expert Group as well as a member of the Department of Health Committee on the Medical Effects of Air Pollutants. He is currently a member of the DEFRA Air Quality Expert Group, the DEFRA Advisory Committee on Hazardous Substances and the DEFRA Expert Panel on Air Quality Standards.

Contributors

Rob Aitken, Institute of Occupational Medicine, Research Avenue North, Riccarton, Edinburgh, EH14 4AP, Scotland, UK

Jon Ayres, Liberty Safe Work Research Centre, Foresterhill Road, Aberdeen AB25 2ZP, Scotland, UK

Ken Donaldson, MRC/University of Edinburgh Centre for Inflammation Research, ELEGI Colt Laboratory, Queen's Medical Research Institute, 47 Little France Crescent, Edinburgh, EH16 4TJ, Scotland, UK

Roy Harrison, Division of Environmental Health & Risk Management, School of Geography, Earth & Environmental Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK

Fintan Hurley, Institute of Occupational Medicine, Research Avenue North, Riccarton, Edinburgh, EH14 4AP, Scotland, UK

Jamie Lead, Division of Environmental Health & Risk Management, School of Geography, Earth & Environmental Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, England, UK

David Mark, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, SK17 9JN, England, UK

Andrew Maynard, Wilson International Center for Scholars, One Woodrow Wilson Plaza, 1300 Pennsylvania Ave., NW Washington, DC 20004-3027, USA

Barry Park, Oxonica Limited, 7 Begbroke Science Park, Sandy Lane, Yarnton, Kidlington, Oxfordshire, OX5 1PF, England, UK

Vicki Stone, Centre for Health and Environment, School of Life Sciences, Napier University, Merchiston Campus, Edinburgh, EH10 5DT, Scotland, UK

Lang Tran, Institute of Occupational Medicine, Research Avenue North, Riccarton, Edinburgh, EH14 4AP, Scotland, UK