Environmental Engineering and Management Journal January/February 2009, Vol.8, No.1, 191-194
http://omicron.ch.tuiasi.ro/EEMJ/

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Book Review

NANOTECHNOLOGY
Volume 2: Environmental Aspects

Harald F. Krug (Editor)
WILEY-VCH Verlag GmbH&Co. KGaA, Weinheim, Germany
ISBN: 978-3-527-31735-6, XV+317 pages, 2008

The second volume of the book "Nanotechnology" edited by Harald F. Krug demonstrates the multifaceted correlation between *Nanotechnology* and environmental problems.

The progress in science recorded during the past two decades on the on hand, and the demand for higher safety and the regulation of new technologies on the other hand, highlight the fact that today the use of nanomaterials within the environment is a very sensitive issue.

Environmental problems addressed in this book cover the use of nanomaterials as catalysts to reduce or prevent pollution or identify the situation both early and accurately, to solving energy-related problems by applying nanotechnology or addressing environmental difficulties arising during the production and use of nanoparticles.

The feat is structured in ten chapters writhen by authors from prestigious universities and institutes from United Kingdom, Germany, USA, Switzerland, Thailand, Denmark.

The first chapter, "Pollution Prevention and Treatment Using Nanotechnology", author Bernd Nowack, gives a general overview of potential environmental applications of nanotechnology and nanoparticles being a short overview of the current knowledge about possible risks for the environment. Pollution prevention by nanotechnology refers on the one hand to a reduction in the use of raw materials, water or other resources and the elimination or reduction of waste and on the other hand to more efficient use of energy or involvement in energy production.

The implementation of green chemistry principles for the production of nanoparticles and for nanotechnological applications in standard chemical syntheses improved catalysis and finally inherently safer chemistry.

However, replacing traditional materials with nanoparticles really does result in less energy and materials consumption and that unwanted or unanticipated side effects do not occur.

Nanostructured materials are applied in Pollution Detection and Sensing, Water Treatment, Adsorption of Pollutants, Magnetic Nanoparticles, Nanofiltration, Degradation of Pollutants, Zerovalent Iron, Soil and Groundwater Remediation, Ecotoxicology.

It is recommended that a careful weighing up of the opportunities and risks of nanotechnology with respect to their effects on the environment is needed.

Chapter 2, "Photocatalytic Surfaces: Antipollution and Antimicrobial Effects", authors Norman S. Allen, Michele Edge, Joanne Verran, John Stratton, Julie Maltby and Claire Bygott, discusses first about titanium dioxide chemistry and structure-activity that many years, has been used successfully for conferring opacity and whiteness to a host different materials. The primary reason for its success is the ability to reflect and refract or scatter light more efficiently than any other pigment, due to its high refractive index in comparison with extenders, fillers and early pigments. Based on the light scattering property described in this chapter, nanoparticles titanium dioxide can be used to impart excellent UV protection. Compared with the available UV absorbers, ultrafine TiO_2 possesses effective UV filter properties over the entire UV spectrum.

Titan dioxide is used antibacterial, self-cleaning and depollution [atmospheric contaminants such as volatile organic compounds (VOCs) and nitrogen oxides]. The antibacterial activity of the nanoparticles pigments was inversely proportional to particle size and relates to their intrinsic ability to generate active carriers giving rise to active surface species.

Photocatalytic cementations materials offer significant advantages from an environmental point of view on all issues associated with long-term activity, durability, self-cleaning and depollution of NOx and VOCs.

Chapter 3, "Nanosized Photocatalysts in Environmental Remediation", authors Jess P. Wilcoxon and Billie L. Abrams, emphasize the key approaches to photocatalyst synthesis and characterization and the most salient research issues for the future. Following a review of the general field of environmental remediation, a historical background of the field is given with emphasis on the properties of titanium dioxine, since studies of the photophysical properties of this material have dominated the literature. Then selected photocatalysis studies and research findings associated with TiO_2 are discussed followed by analysis of research concerning layered semiconductors such as MoS_2 as photocatalysts.

The ability to adjust the adsorption onset and redox potential with size and surface chemistry in nanosized materials provide new opportunities in photocatalysis. Finally, exemples are given of recent technical application of TiO_2 semiconductors such as self-cleaning tiles and windows enabled by scientific research on TiO_2 photocatalysis. Nanosized photocatalysts for environmental remediation can be a viable approach to photo-oxidation and removal of organic and inorganic pollutants in water and air. This process for photocatalytic oxidation of pollutants produces relatively benign products such as CO_2 and dilutes mineral acids under ambient conditions. Potentially, it can be driven entirely by sunlight, minimizing its economic costs.

Chapter 4, "Pollution Treatment, Remediation and Sensing", authors Abhilash Sugunan and Joydeep Dutta, approaches environmental protection and pollution issues frequently discussed worldwide as topics that need to be addressed sooner rather than later. Nanotechnology can strive to provide and fundamentally restructure the technologies currently used in environmental detection, sensing remediation and pollution removal. New advances have emerged in the use of nanotechnology in environmental protection.

Topics such as treatment technologies to remove environmental pollutants, remediation technologies to clean up environmental pollutants effectively, sensors, biosensors, electrochemical sensors, mass sensors, optical sensors, gas sensors, novel sensing technologies and devices for pollutant and microbial detection, real-time chemical composition measurements of fine and ultrafine airborne particles, ultrasensitive detection of pathogens in water, detection of heavy metals in water are discussed. This chapter provides just a small beginning to the exciting new applications envisaged for the "small world" of nanotechnology for preventing environmental pollution.

Chapter 5, "Benefits in Energy Budget", author Ian Ivar Suni, deals with application of nanomaterials in the field of energy which include fuel cell catalysts, fuel cell support materials, hydrogen storage, solar cells, lithium ion batteries and supercapacitors. The current discussion focuses on recent results, on clear demonstrations of the utility of nanomaterials and on the scientific basis for these applications. Applications of nanomaterials in: fuel cells, low-temperature fuel cell technology, nanoparticle catalyst support materials, carbon nanotubes: science and technology, carbon nanotubes within operating PEMFCs, hydrogen storage, hydrogen storage using carbon nanomaterials, solar cells, solar energy basics, including quantum confinement, nanocrystalline dye-sensitized solar cell, nanomaterials in solar cell counter electrodes, lithium ion battery anode materials, lithium ion batteries, nanomaterials for lithium ion storage: nanoparticles, nanomaterials for lithium ion storage: nanocomposites, nanomaterials for lithium ion storage: carbon nanotubes and carbon nanotubes-based composites, lithium ion storage are analyzed.

Chapter 6, "An Industrial Ecology Perspective", authors Shannon M. Lloyd, Deanna N. Lekas, and Ketra A. Schmitt, describes several IE concepts: life cycle assessment (LCA), material flow analysis (MFA), substance flow analysis (SFA) and corporate social responsibility – and explore their implication and application to nanotechnology. IE provides a framework for analyzing the impacts of nanotechnology on social and ecological systems. A number of IE tools, including LCA, MFA, SFA and CSR, can aid in assessing the potential risks and benefits of nanotechnology, in addition to developing methods to reduce or mitigate potential risks. When applied prospectively, IE tools can be used to provide a forward-looking analysis that permits the design and manufacture of nanotechnology-based products in a manner that prevents or reduces their negative impacts.

Chapter 7, "Composition, Transformation and Effects of Nanoparticles in the Atmosphere", author Ulrich Poschl, considers the effects of airborne particles in the nanometer to micrometer size range (aerosols) on the atmosphere, climate and public health as among the central topics in current environmental research. The particles scatter and absorb solar and terrestrial radiation, they are involved in the formation of clouds and precipitation as cloud condensation and ice nuclei and they affect the abundance and distribution of atmospheric trace gases by heterogeneous chemical reactions and other multiphase processes. The concentration, composition and size distribution of atmospheric aerosol particles are temporally and spatially highly variable.

Accurate determination of the chemical composition of air particulate matter is a formidable analytical task. Carbonaceous aerosol components as organic compounds and black or elemental carbon account for a large fraction of air particulate matter exhibit a wide range of molecular structures and have a strong influence on the physicochemical, biological and climate- and health-related properties and effects of atmospheric aerosols. Chemical reactions proceed at the surface and in the bulk of solid and liquid aerosol particles and can influence atmospheric gas-phase chemistry and properties of atmospheric particles and their effects on climate and human health.

Anthropogenic emissions are considered as major sources of atmospheric aerosols. In particular, the emissions of particles and precursor gases from biomass burning and fossil fuel combustion have increased massively since pre-industrial times and account for a major fraction of fine air particulate matter in polluted urban environments and in the global atmosphere (carbonaceous components, sulfate etc.). Efficient control of air quality and related health effects requires a comprehensive understanding of the identity, sources, atmospheric interactions and sinks of hazardous pollutants.

Without this understanding, the introductions of new laws, regulations and technical devices for environmental protection runs the risk of being ineffective or even of doing more harm than good through unwanted side-effects. Outstanding open questions and research aims for the elucidation of aerosol effects relevant for the science and policy of change have been outlined in several recent monographs, review and research articles. As far as chemical transformation, heterogeneous and multiphase reactions and gas-particle interactions of aerosols and clouds are concerned, one of the most important prerequisites for efficient further investigation and scientific progress is the establishment of a common basis of consistent, unambiguous and universally applicable terminologies, model formalisms and kinetic thermodynamic parameters. For efficient elucidation and abatement of adverse aerosol health effects, the knowledge of atmospheric and biomedical aerosol research should de integrated to formulate plausible hypotheses that specify potentially hazardous chemical substances and reactions on a molecular level.

Chapter 8, "Measurement and Detection of Nanoparticles within the Environment", authors Thomas A.J. Kuhlbusch, Heinz Fissan, and Christof Asbach defines nanoparticles as intentionally produced particles for use in products either as single particles or as agglomerates with diameters below 100 nm. Another term often used is ultrafine particles. Ultrafine particles in this chapter denote particles in the environmental which at least partially consist of unintentionally produced and/or naturally formed particles. Nanoparticles are normally solid particles whereas naturally and unintentionally manmade particles may be of solid or liquid nature. Even though particles in the sub-100-nm range can be differentiated into nanoparticles and UFPs, the measurement and detection techniques are fundamentally the same.

One further issue when discussing nanoparticles in the environmental is the stability of nanoparticle agglomerates and agglomerates of nanoparticles. The environment and environmental matrix containing nanoparticles are considerate of crucial importance for the detection and measurement of nanoparticles. Generally three matrices can be differentiated in the environment: soils, water and air. These three matrices differ not only in their physical state (solid, liquid and gas) but also in their mobility, increasing from soils to air. This mobility and the mobility of nanoparticles dissolved in these matrices are of great importance when assessing the risk.

Concerning the occurrence of nanoparticles in environmental media mainly two different environments can be differentiated when discussing nanoparticles: the ambient environment and plants or workplaces in nanoparticle production, handling and processing. The environmental media in which nanoparticles may occur are the same, but the media soil and water will only be discussed for the ambient, public environment since the information given there is also valid for the work environment. The detection and measurement strategies to be pursued depend mainly on the nanoparticle characteristics and on the detection limits. Nanoparticle characteristics can be divided into physical-chemical and morphological characteristics. The physical-chemical characteristics determine, for example, which detection technique can be used for the identification of the nanoparticles.

Chapter 9, "Epidemiological Studies on Particulate Air Pollution", authors Irene Bruske-Hohlfeld and Annette Peters, presents an overview of the main results stemming from epidemiological research on the health effects of exposure to particulate air pollution in the environment and at the workplace. Although remarkably consistent between numerous epidemiological studies in different geographic areas, these findings were at first received with some skepticism, as there appeared to be no plausible biological mechanism to explain the observed association between respiratory and cardiovascular mortality and the level of airborne particles.

As epidemiology is an observational rather than an experimental science, it cannot establish causality on its own and is a rather blunt tool for elucidating biological mechanisms. Exposure to nanoparticles is more likely to happen after the manufacturing process itself, except in those cases of failures during the processing. In processes involving high pressure (e.g. supercritical fluid technique) or with high-energy mechanical forces, particle release could occur in the case of failure of sealing of the reactor or the mills. Furthermore, many particles, including metallic particles, are highly pyrophoric and there is a considerable risk of dust explosions.

Chapter 10, "Impact of Nanotechnological Developments on the Environment", authors Harald F. Krug and Petra Klug, analyses some aspects concerning risk management, sources of nanoparticles: new products, production and use of nanomaterials, workplace ant the environment: effects and aspects of nanomaterials, distribution of nanoparticles in ambient air, distribution of nanoparticles in water. Contact with nanomaterials should be given increased attention during development in the research laboratory and also during large-scale technical production since the unique properties of the new materials are able to show not only technical but also biological effects, and that the behavior of the nanoparticles toward bulk materials will certainly be changed.

The field of nanotoxicology can only be approached in multidisciplinary way, that is, addition to industry and the agencies, also chemists, physicists, materials scientists, engineers, medical professionals, biologist, toxicologists, ecologists, statisticians and additional branches of study, which have to deal with all aspects of nanotechnology, including the ethical questions and the sustainability of this technology, are also challenged.

Each chapter of the book includes a rich reference list, including significant titles related to the chapter subject. Also, the book ends with a subject index.

In conclusion, this volume-the second in nine-volume series treats environmental aspects, explaining the risk and benefits of nanotechnology. The authors - experts in the field cover aspects on pollution prevention and treatment using nanotechnology, together with the impact of nanomaterials on the environment.

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