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NANOPARTICLES AND OCCUPATIONAL HEALTH

Editorial

Recent advances and new challenges of occupational and environmental health of nanotechnology

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Abstract An overview of the special issue of the Journal of Nanoparticle Research on Occupational and Environmental Health of nanotechnology is presented. Papers published in this special issue show considerable progress in understanding nanoparticle toxicity, monitoring, generation, dustiness, filtration, and applications of nanoparticles. More research is needed to ensure safe handling of nanomaterials as nanotechnology continues to develop at an incredible pace.

Keywords Nanotechnology · Health and safety · Nanoparticles · Occupational health · Environmental health · Exposure assessment

The development and commercialization of nanotechnologies are proceeding at an incredible pace. Many consumer products using nanotechnology are already available and more sophisticated products, processes and applications are under development. At the same time, potential negative side effects of nanotechnology are being increasingly questioned. There are fears that innovation without a sound understanding of risk will lead to unanticipated harm to human health and the environment, or to a wholesale rejection of emerging nanotechnologies. Coordinating and applying critical risk-based research are essential to ensure the development of responsible, sustainable nanotechnologies and to remove these fears.

The 3rd International Symposium on Nanotechnology-Occupational and Environment Health was held successfully from Aug. 29 to Sep. 1, 2007, in Taipei, Taiwan.[1] Building on two previous successful symposia in the UK (Mark 2005) and the USA (Maynard and Pui 2007), this symposium brought together 301 key researchers and practitioners from 21 countries to share the latest knowledge on identifying and assessing the potential risks of nanoparticles to occupational health and environment, and the latest findings of monitoring and characterization of nanoparticles and nanotechnology applications in remediation and control of risks.

There were three keynote speeches:

(1) Safe Nanotechnology—where are we now and where are we going?
Speaker: Dr. Andrew D. Maynard, Project on

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[1] The 3rd International Symposium on Nanotechnolgoy, Occupational and Environmental Health: http://nano-taiwan.sinica.edu.tw/2007_EHS2007/index.htm. Accessed June 2008.

Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars, USA

(2) Global Aspects of Nanotechnology Risk Governance
Speaker: Dr. Mike Roco, National Science Foundation, USA

(3) Integrated Processes for Nanomaterial Production
Speaker Dr. Bernd Sachweh, BASF, Germany

Totally, 169 papers were presented in the platform and poster sessions in the areas of nanomaterials and health risk, nanoparticle monitoring and characterization method, environmental applications of nanotechnology, dustiness of nanomaterials, good working practices, emission control and exposure protection, and international standard and nanotoxicity.

Most of the articles in this special issue are invited papers from the 3rd International Symposium on Nanotechnology, Occupational and Environmental Health. Totally, there are 19 papers, of which one is the overview of nanotoxicity program in NIOSH, five deals with and nanoparticle toxicity, nine are related to monitoring and characterization of nanoparticles, and four are concerned with nanoparticle filtration and environmental applications.

The National Institute for Occupational Safety and Health (NIOSH) has developed a strategic plan for nanotechnology safety and health research, which identified knowledge gaps and critical issues to ensure safe working environment of nanotechnology-related processes. In this issue, Castranova discusses the projects and the progress of the Nanotoxicology Program in NIOSH, including pulmonary toxicity, systemic effects, dermal effects, and development of predictive algorithms for naonotoxicology. The paper by Yu et al. demonstrates that amorphous silica nanoparticles below 100 nm induced cytotoxicity in mouse keratinocytes, and nanoparticle size was shown to be a critical factor. Lin et al. reported both 70 and 420 nm ZnO particles reduced viability of human lung epithelial cells significantly and exhibited a much steeper response pattern than other metal oxides, Al_2O_3, TiO_2, and CeO_2. Particle mass-based and specific surface area-based dosimetries were found to result in two different dose-dependent cytotoxicity patterns. Wang et al. investigated the neurotoxicity and the size effect of low-dose, repeated intranasal instillation of nano- and submicron-sized Fe_2O_3 particles. The results indicated nanoparticles could induce more severe oxidative stress and nerve cell damage in the brain of the mice than the submicron particles did. Kim et al. compared the toxicity of nano- and micro-sized SiO_2 and TiO_2 particles in vitro and in vivo. The cell viability of all test particles was found to decrease with increasing dose, with nano-SiO_2 exhibiting a much sharper decrease of cell viability compared to other particles. More pulmonary injury and neutrophilic infiltration were observed in nano-sized than micro-sized particles. Zhu et al. tested six different nanomaterials in the 48-h acute toxicity test of Daphnia magna, using immobilization and mortality as toxicological endpoints. Their results showed that the acute toxicities of all tested nanomaterials were dose dependent, and TiO_2-, Al_2O_3-, and carbon-based nanomaterials were more toxic than their bulk counterparts.

Characterizing the nanoparticle dispersion state (such as size and surface charge) in the solution and understanding the parameters that affect this state are imperative for nanoparticle toxicity investigations. Jiang et al. showed that both adsorbing multiply charged ions (e.g., pyrophosphate ions) onto the TiO_2 nanoparticle surface and coating quantum dot nanocrystals with polymers (e.g., polyethylene glycol) suppress agglomeration and stabilize the dispersions. Probe sonication was found to perform better than bath sonication in dispersing TiO_2 agglomerates when the stabilizing agent sodium pyrophosphate was used. For inhalation toxicology study, Myojo et al. developed a fibrous aerosol generation system consisting of a rotating brush aerosol generator and a two-component fluidized bed to fully disperse a multi-wall CNT (MWCNT). The carbon mass in CNT aerosol samplers was quantified by a carbon analyzer. Their results showed that dispersed aerosol concentration of the system was relatively stable.

Nanoparticle surface area may be more relevant to nanoparticle toxicity, and hence surface area measurement of nanoparticles is important. The Nanoparticle Surface Area Monitor (NSAM, TSI model 3550) determines lung-deposited particle surface area concentrations, based on the ICRP model. Accuracy and conceptual limitations concerning particle and aerosol properties are discussed in the paper of Fissan et al. To meet the need of developing a low-cost and portable device capable of measuring size distribution of nanoparticles, Chen et al. proposed a scheme to use a commercially available instrument, EAD (TSI Model 3070A), as a nanoparticle sizer. Excessive levels of nanoparticle emissions during the handling and transport of nanomaterials can cause adverse health effects on workers and may pose fire explosion hazards. It is therefore important for industrial hygienists to understand the propensity or dustiness of nanopowders for the purpose of risk assessment and control. Tsai et al. used a standard rotating drum tester with a sampling train to determine the number and mass distributions of the generated particles from nano-TiO_2 and fine ZnO powders. They found that very few particles below 100 nm were generated, and the released rate of particles decreased with increasing rotation time for both nanopowders. Due to the fluffy structure of the released TiO_2 agglomerated particles, the mass distributions measured by the MOUDI showed large differences with those determined by the APS, assuming the apparent bulk densities of the powders. The differences were small for the ZnO agglomerates, which were more compact than the TiO_2 agglomerates. Jensen et al. found that low-pressure compaction may reduce the risk of nanoparticle exposure if nanopowders are handled in operations with few agitations such as pouring or tapping. Repeated agitation, e.g., mixing, of compacted powders would result in reduced or highly increased dustiness depending on the type of nanopowders. Laboratory fume hood is an important tool to protect workers handling nanomaterials from exposure to airborne nanoparticles. In the paper by Tsai et al., they found that handling of dry nanomaterials could result in a significant release of airborne nanoparticles from the fume hood into the laboratory environment and the researcher's breathing zone. Many variables were found to affect the amount of particle release, including hood design, hood operation, work practices, type and quantify of the nanomaterials being handled, and the general ventilation conditions.

Airborne nanoparticles released from handling of dry nanomaterials often exist as aggregates. Different monitoring and sampling methods are based on different equivalent diameters; therefore, it is important to relate one equivalent diameter to the others. Shin et al. used three different methods to obtain the relationship between the projected area equivalent diameter and the mobility diameter of the laboratory-generated silver agglomerates. Fractal dimensions based on different methods were also obtained. The number of primary particles obtained from the projected surface area using a previous empirical equation was found to be larger than those obtained from the projected area measurement directly or from the mobility analysis. Park et al. investigated the effect of structural properties of NaCl and $(NH_4)_2SO_4$ nanoparticles on the deliquescence relative humidity (DRH) and hygroscopic growth factor (GF). They found the effect is more pronounced at smaller diameters.

Filtration is an important technology for nanoparticle control and reduction of human exposure to nanoparticles. Filtration by noncircular fibers is gaining more attention in search for better filter quality. Elliptical fibers have extra significance because they may be used in simple models of dust loading. The paper of Wang and Pui uses numerical simulation to investigate filtration by fibers with elliptical cross sections. They found that blunt and close to circular fibers perform better for particles dominated by the effects of interception and inertial impaction, whereas long and slim fibers perform better for particles dominated by the diffusion effect. For very small nanoparticles, the diffusion effect was found to be important, and long and slim elliptical fibers might improve the filter performance. The paper by Podgorski is on the study of the nanoparticle penetration in polydisperse fibrous filters using the fully segregated flow model (FSFM). Results showed that the apparent exponent of the Peclet number based on the mean fiber diameter is greater than the expected value of $-2/3$ for diffusional deposition in a monodisperse filter. The FSFM is expected to be the estimation of the upper limit of nanoparticles penetration in polydisperse fibrous filters.

In the environmental applications of nanotechnology, Lee et al. investigated the influence of noble and platinum group metal deposits on the photocatalytic performance of TiO_2 for the gas-phase degradation of toluene. Intermediates formed during toluene degradation remain on the TiO_2 surface leading to photocatalyst deactivation. With the exception of Ag, the metals deposited on TiO_2 (Au, Pt, Pd, Rh) were found to inhibit photocatalyst deactivation by improving degradation of these intermediates. However, the metal deposits did not increase the rate of toluene degradation. The Pt deposits were found to display a marked improvement over the other metals in inhibiting photocatalyst deactivation. The effect was tentatively ascribed to the smaller deposit size and higher dispersion relative to the other metals considered. Yang and Chan demonstrated that sensitizing nanoscale ZnO with Alizarin Red S for photocatalytic treatment of chromium(VI)-bearing wastewater using visible light is feasible.

The next international symposium will be held in Helsinki, Finland, August 26–29, 2009 (http://www.ttl.fi/nanoeh2009). The Symposium will be organized by the Finnish Institute of Occupational Health (FIOH), with co-organizers from four other Finnish institutions and six EU countries. With recent emphasis and funding increases by the US and EU agencies, we expect a high turnout for this symposium that will make it an important platform for communicating the latest research results and actions to assure the safety and the successful implementation of nanotechnologies.

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