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Editorial

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Editorial: Sustainable Nanotechnology

This special issue represents research papers presented at the second Conference of the Sustainable Nanotechnology Organization (SNO)—a nonprofit, international, professional society. Dr. Arturo Keller of the University of California at Santa Barbara chaired the meeting in November of 2013. The organization focuses on advancing sustainable nanotechnology around the world through education, research, and the promotion of responsible use of nanotechnology (www.susnano.org). The conference brought together over 200 scientists and experts from the academia, industry, and government agencies to present and discuss current research findings on the subject of nanotechnology and sustainability.

In attendance were participants from almost all of the states in the United States, as well as international participants from Canada, France, Great Britain, India, Korea, Japan, and Poland. There was also a sizable presence of students at the conference, which indicated the "recentness" of the field, and these young scientists brought a fresh appeal to the field. The annual conference of SNO is a place where the new community of sustainable nanotechnology is being formed and advanced. Although SNO is a relatively new organization, there is ample evidence that the organization is building a firm base of diversity to carry it into a strong and sustainable future.

Sustainable nanotechnology is the research and development of nanomaterials that have economic and societal benefits with little or no negative environmental impacts. The successful application of nanotechnology is contingent upon scientific excellence that provides economic, ethical, and societal benefits. Contributors to this issue truly reflect the critical elements and the challenges we face as nanotechnology transitions from the research laboratories to the society at large. Aspects of sustainable nanotechnology covered in this issue ranged from green synthesis of nanomaterials (Lahr and Vikesland, Punnoose, Mallikarjuna and Markova); green energy and catalysis (Varma, Virkutyte, and Gowande); methods and analytical tools (Sadik, Yang, Pyrgiotakis and Suni); sustainable manufacturing (Raveendran); nano life-cycle assessments (Keller and Lazarewa); environmental applications (Craver, Achintya, Eckelman, Reed, Sadik); and nanotoxicity (Raveendran, Veronesi, Shvedova and Zuo); as well as fate/transports of nanomaterials (Yang). Although, not covered in this issue, nanomedicine, societal, and policy considerations are important components of sustainable nanotechnology.

Two papers discussed the applications of nanomaterials for more efficient catalysis. Virkutyte and Varma modified a clay with iron oxide to form an effective catalyst to degrade organic contaminants, while Gawande et al. presented a recyclable catalyst for pyrazole derivatives and Ulmann-type condensations.

Four papers discussed the issue of "green synthesis of nanomaterials". Lahr and Vikesland used SERS to further elucidate the mechanisms of Au nanoparticles biosynthesis by algae. Punnoose et al. studied the change in toxicity of ZnO nanoparticles prepared using two different solvents (diethylene glycol and ethanol), which yielded different surfaces and toxicities. Mallikarjuna et al. and Markova et al. presented two papers using natural products to synthesize nanomaterials. Thereafter, they used antioxidants found in fruits and spices to synthesize Ag nanoparticles and Au nanoparticles and the synthesis of nanoscaled iron in green tea. In the latter paper, these researchers found an increase in ecotoxicity over those found for Fe nanoparticles that were synthesized by other methods.

Six papers emphasized methods and analysis: Sadik et al. conducted a survey of methods used to measure nanoparticles in complex matrices and described a unique, portable, nanoparticle analyzer based on tangential flow. Yang et al. developed a statistical method known as "kriging" to efficiently model the exposure−response surfaces by pooling information on toxicity across multiple data sources. Erbis presented a stochastic programming for carbon nanotube production. Pyrgiotakis used AFM to study real-time nanoparticle−cell interactions in physiological media, while Suni et al. discussed nanoenabled impedance biosensors.

Three articles presented research using nanomaterials for water treatment. Rodrigues et al. showed the enhancement of membrane filters coated with combinations of poly(*N*-vinylcarbazole) and graphene oxide and with PVC−graphene. Bezbaruah et al. used nano-zero-valent iron (nZVI) to remove phosphate from lake water and recycled the iron−phosphate as an effective nutrient for plant growth. Craver et al. used nanomaterials as sorbents to enhance the quality of surface runoff.

Industrial ecology methods were presented in two papers. Espinoza et al. developed a material flow analysis for CNT−LI ion batteries to help inform potential end-of-life exposures. Using a life cycle and material flow approach, Lazareva and Keller compared potential exposures to 11 engineered nanomaterials used in more than a dozen applications from released wastewater treatment plants in major cities around the world.

Five papers addressed nanotoxicity and ways to lower it. Raveendran et al. discussed how to stabilize and lower toxicity by coating ZnSiMn quantum dots with a polysaccharide produced by extremophilic bacteria. Veronesi et al. studied the effects of coating, size, and aggregation for Ag nanoparticles on neural cells. Shvedova et al. found differences in the toxicity of nanocellulose depending on processing of the material. Coated polymer nanoparticles were studied by Zuo et al. to obtain different surface charges to study the effects of hydrophobicity on lung cells. Reed et al. examined nanoscaled metals contained in dietary supplement drinks and determined their effects on intestinal cells. Potential exposures from wastewater were also discussed.

All of the papers in this issue continued with ongoing discussions as well as future directions. We invite readers to join

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us at SNO for further research and the discussion of sustainable nanotechnology as we define a pathway forward.

We hope you enjoy reading this issue.

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Notes

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