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EDITORIAL

Analytical developments in advancing safety in nanotechnology

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It is evident that nanotechnology has created a new era of transformative science [1–3]. Nanomaterials have unique properties that are dramatically different from those of bulk materials, and also require more stringent experimental conditions in preparation, characterization, and applications. Analytical science is pivotal to advance our understanding of the complex behavior observed with engineered nanomaterials. For example, analytical technologies must shed light on the elemental composition and the size distribution of the sample with unprecedented accuracy. The implementation and design of experiments involving nanoscale phenomena have stretched the limits of the tools currently available to evaluate nanoscale systems. This has led to the pursuit of new analytical approaches and enabling technologies to sustain continued innovation through nanotechnology. Many of these exciting analytical advances have recently been described in this Journal [4–10].

Responsible implementation of nanotechnology prompts a new and multifaceted perspective on safety. Safety in nanotechnology encompasses more than practices in the laboratory and in manufacturing. The integrity of a commodity made with nanomaterials must be sustained beyond the lifetime of the product, which requires an understanding of the molecular interactions of nanoparticles. As so much has yet to be clarified within the field of nanotechnology, the impacts that engineered nanomaterials have on environmental and human health are unclear. Elucidating these impacts challenges existing research paradigms [11] because following production nanomaterials can go through diverse pathways. Different mechanisms of nanoparticle transformation are known and therefore must be considered. For example, nanoparticles may collect contaminants from the surroundings. They may slowly dissolve; thereby, changing the concentration of materials in a local environment. Nanoparticles may convert harmless chemicals into different chemical species with unknown toxic effects through the photocatalytic production of reactive oxygen species. Nanoparticles may become airborne, which allows them to be inhaled and potentially lead to toxicity effects as observed with asbestos. Any potential for media-induced differences in particle aggregation must be taken into account. Likewise, proteins, lipids, and other biomolecules in solution may lead to the formation of a biofilm, which will dramatically influence the chemical and physical properties of the nanomaterials.

National and international regulatory and research organizations have offered advice regarding the handling, disposal, and delivery of nanomaterials under different circumstances [12–16]. One such ongoing national effort is the research supported by National Institute of Environmental Health Sciences on gaining fundamental understanding of engineered nanomaterial interaction at the cellular and organ systems level through Nanotechnology Health Implications Research (NHIR) consortium. As the field progresses, more information about nanomaterials, interactions within the biological systems and their transformation, as well as interaction with the cellular organelles will guide the responsible use of this technology which holds promise to advance society in so many positive ways. Articles within this topical collection address these topics through proposed strategies to test nanomaterial safety [17, 18] as well as nanomaterial stability [19] and sample handling [20]. New models to evaluate toxicity including heart-on-a-chip [21] and system-wide proteomics [22] approaches to evaluate biological response are presented as well as an in-depth study of how nanoparticles impact wastewater treatment [23]. New approaches to evaluate nanoparticles are addressed in this topical collection as well, including a report on evaluation of the interaction of nanoparticles with lipids [24] and a review of

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emerging analytical technologies for the detection of reactive oxygen species [25]. Finally, the role of analytical technology in nanotechnology education and educational strategies to sustain a vibrant workforce through academic research experiences is discussed [26]. Nanotechnology has captured the attention of researchers in all areas of science dedicated to identifying safe nanomaterials that will continue to advance manufacturing, commercialization, and scientific research in diverse fields such as biotechnology, energy production, wastewater treatment, and chemical synthesis. We thank the contributors and editors for the opportunity present this topical collection.

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