Nanotoxicology: Doing it by the Numbers

Predicting Toxicity Before Manufacturing

Interested Agencies: CPSC, DOD, DOE, DOL, DOT, EPA, FDA, NIOSH, NIH, NIST, NSF

The behavior of engineered nanoscale materials in biological systems is directly related to the physical and chemical properties of that material. The rapidly increasing number of nanomaterials in development and manufacture, as well as the exquisite sensitivity of a material to its biological microenvironment, makes it difficult to predict biocompatibility or toxicity in humans and the environment. Currently, decisions to proceed to manufacture or to release products for commercial use are based on laboratory assessments of toxicity.

Conventional toxicity assessment often employs a tiered system of assays. A material that gives positive indications of toxicity in the first-tier assessment is then analyzed more rigorously in a dose-response model. These data, plus exposure measurements from the exposure site, are analyzed, and an estimate of risk is calculated. These analyses are frequently time-, nanomaterial-, and equipment-intensive. Computational models that predict biological and environmental response of a new material based on knowledge of structurally similar materials have been developed for several classes of chemicals.

Vials of quantum dots and blood plasma following centrifugation, part of a study of the effects of quantum dots on immune cell function. Such studies are used to evaluate the safety of nanomaterials in humans. Computational methods could augment or replace these time-consuming and expensive laboratory tests. (Image courtesy of NCL).

Development of similar predictive models for nanomaterials will require a thorough understanding of the biological interaction of a few well-characterized standard nanomaterials in well-characterized biological and environmental systems. These data would be used to define basic structure-activity relationships and would serve as the basis for creating models that predict the biological and environmental response of new or more complex nanomaterials. Development of the computational components of a predictive model would occur in parallel with the biology studies and require translation of the models for chemicals to nanoparticles and complex three-dimensional nanoscale structures.

The ability to predict biological and environmental response to nanomaterials through a computational model and to adjust physical and chemical parameters of the materials early in product research and development has the potential to shorten the time for toxicity testing from several weeks to a matter of hours. It will also provide a labor and cost benefit to the manufacturer, new tools for risk assessment by regulatory agencies, and protection of humans and the environment from harmful exposures.