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Testing in EHS: What is the Current Status of Experimentation?

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Abstract

This paper explores some of the fundamental and practical issues related to the behavior of nanoparticles in the environment and their potential impacts on human health. In our research we have explored the reactive behaviors of nanoparticles with contaminants in the environment, how nanoparticle change in response to their environment and time, and how nanoparticles interact with biological systems of various types. It has become apparent that researchers often underestimate the difficulties of preparing and delivering well characterized nanoparticles for specific types of testing or applications. Difficulties arise in areas that range from not understanding what imparts the “nano” character of a particle to not knowing the impacts of minor species on the properties of high surface area materials. Some of our adventures and

misadventures serve as examples of some of these issues as they relate to providing well defined particles for biological studies.

I. Introduction

Because of the increasing use of nanoparticles in a wide variety of applications[1] their potential impact on environmental and human health is likely to grow. For example, several forms of nanoparticles are routinely used in cosmetics, are being designed to improve medical diagnostics and treatment [2], and are used in the design of light weight strong composites. They are often included as functional components of sensors, have antimicrobial properties important to environmental safety and may be used to help remediate environmental contamination[3]. They may also offer routes for the development of clean energy production and energy storage[4]. Along with the growing use of nanomaterials in a variety of technologies there are concerns (both real and perceived) about environmental and health risks associated [5] with nanostructured materials.

In addition to the increased use of nanomaterials there is a growing recognition that nanoparticles and other nanostructured materials have often been inadequately characterized and that this lack of adequate characterization may limit or even invalidate some of the conclusions regarding particle properties and behavior [6–9]. In our research we have frequently faced questions relating how to synthesize particles with desired properties and surface composition, how to characterize particles with a combination of in situ and ex situ methods without introducing artifacts, and how to deliver particles with well-defined properties when those properties can vary with time and alter as the environment is changed. Among the difficulties are particle agglomeration, contamination, and phase and chemical state changes.

When particles are introduced into a biological system for either medical or toxicological studies the issues associated with the characterization and changes in properties of particles are compounded. In studies of toxicology it is important to understand how particle migrate and to understand what particle dose applies for any observed effects. When in a complex environment a nanoparticle is not the initial “pristine” particle produced and measured in the ideal system but is covered by an assortment of molecules attached to the particle surface from the solution. Effectively there is a new particle that consists of the original particle as the core, but with an outer surface made up of molecules adsorbed to the particle surface.

In the effort to identify how studies and measurements need to be done, we explore some of the observations that we have made in our work:

1. There is a common misconception that anything of nano-size (100 nm or less) has some type of “nano” behavior or at least that the important properties vary monotonically with size. The critical size for which particle properties differ from bulk properties – part of what makes a particle truly nano – depends on the material and the specific properties of interest. Some types of materials keep the same phase, but may change the lattice constant as size decreases. Other particles may alter their phase (and significantly change chemical properties), while magnetic

properties may change for a specific size without other obvious changes in material characteristics [10]. Studies examining the impact of nanoparticles of a specific type should consider sizes above and below the size for which a property or behavior of the particle changes.

2. Many types of studies show that the structure and other properties are influenced by the environment around the particle. Therefore measurements made in vacuum may not apply to those made in solution. These changes occur over a period of time and understanding the rate of such transformation in relation to the measurements being undertaken should be a design consideration[11].
3. Relatively subtle changes in synthesis procedures, handling processes, or even storage container can significantly alter the chemical or toxicological behaviors of particles. In studies of iron nanoparticles in the procedures of synthesizing a starting material have significant impacts on reactions with contaminants in solution[12]. In some circumstances researchers with considerable experience conducting “identical” processes consistently produce similar results, but then something changes. We find it necessary to characterize particle surfaces to examine the extent of contamination present and to monitor any other chemical changes to a particle surface.
4. There can be major impact of different solutions on the time dependence of properties of nanoparticles. These impacts can be produced by simply adding a salt or buffer to solution but certainly occur in the presence of dissolved organic material from natural water or for a biological fluid. These effects include significant changes in solubility, formation of a new phase, and significant alteration of solution properties such as the zeta potential.

These and other observations provide the context within which it is possible to understand the behavior of nanoparticles and how they impact their surroundings.

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